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AH-64D Apache Longbow/Video from UAS for Interoperability Teaming Level II (VUIT-2) Aircrew Workload Assessment

by Jamison S. Hicks, David B. Durbin, and LTC Brian Sperling

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14. ABSTRACT

An AH-64D/Unmanned Aerial System (UAS) aircrew workload assessment was conducted during February 2008 in Huntsville, AL. The purpose of the assessment was to evaluate AH-64D aircrew workload during UAS level II interoperability under simulated mission conditions. The workload assessment consisted of operational missions conducted by aircrews (eight pilots) in an AH-64D simulator. Pilot workload, situational awareness (SA), crew coordination, crewstation interface, switch actuations, simulator sickness, visual gaze and dwell times (using a head-eye tracker), audio-video, and tactics, techniques and procedures data were collected and analyzed. Additionally, subject matter experts (SMEs) observed each mission and rated crew workload, crew SA, crew coordination and mission success.

Pilots reported that workload was tolerable for the tasks performed during the missions. The workload ratings provided by the pilots and SMEs were lower than the Objective and Threshold workload ratings requirements listed in the Apache Block III (AB3) Capability Development Document. The pilots reported that they had moderate levels of SA during the missions. Pilots stated that having to interact with an additional sensor (UAS sensor) increased their overall task workload, but the SA provided by the UAS sensor decreased the workload required to detect and engage targets and decreased overall target engagement timelines. Most pilots reported that the UAS crewstation interface was usable, but needed improvements to enhance overall effectiveness. The pilots commented that with several enhancements and more experience using the system, workload would be decreased.

15. SUBJECT TERMS

AH-64D, Apache Longbow, UAS, VUIT-2, pilot workload

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1. Introduction

1.1 Background

The ability to conduct level II interoperability (receiving video feed from an unmanned aerial system [UAS]) adds a new capability to the AH-64D. Specifically, the UAS operates as a remote sensor system, adding an additional sensor system to the AH-64D reconnaissance and targeting systems. The Video from UAS for Interoperability Teaming Level II (VUIT-2) system was designed to provide level II interoperability between the UAS and the AH-64D. This is accomplished by providing real-time streaming video from a UAS sensor to the AH-64D crew and allowing the crew to re-transmit that video (or their aircraft sensor video) to a ground unit equipped with a one system-remote video terminal (OSRVT) or to another airborne OSRVT as needed. The flow of information between the UAS, AH-64D, and OSRVT is depicted in figure 1.

The U.S. Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED) conducted an AH-64D/UAS aircrew workload assessment during February 2008 in Huntsville, AL. The purpose of the assessment was to evaluate AH-64D aircrew workload during UAS level II interoperability (using VUIT-2) under simulated mission conditions.
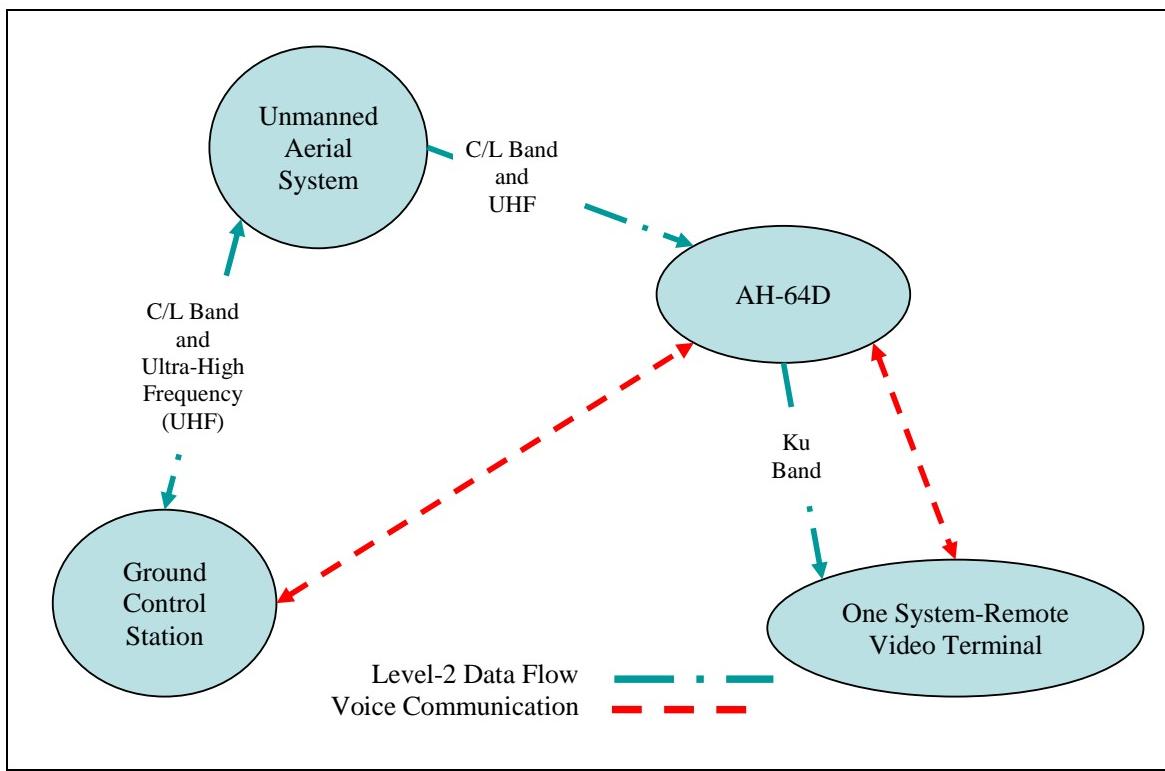
Figure 1. UAS to AH-64D information flow.

1.2   System Description

The major components of the VUIT-2 system on the AH-64D are: a mast-mounted C/L-band omni-directional antenna for reception of UAS video and an ultra high frequency (UHF) antenna for reception of UAS data; an OSRVT and Thermite computer to process received video for presentation on the crewmember-selected multipurpose display (MPD); keyboard style control that permits the copilot gunner (CPG) to interface with the VUIT-2 system; and a mini-tactical common data link (MTCDL) system that permits transmission of received UAS or aircraft sensor video to a ground or airborne OSRVT. The VUIT-2 is incorporated as a strap-on system for Block I and II AH-64Ds involving minimal interface with the current production aircraft bus architecture. The VUIT-2 software version used during this simulation was 1.7.5.

The AH-64D Apache is a twin-engine, tandem-seat, aerial weapons platform built by Boeing Integrated Defense Systems. Aircraft armament includes a belly-mounted slewable 30-mm chain gun, Hellfire missiles, and 2.75-in aerial rockets. The aircraft integrated sensor suite includes a mast-mounted Longbow fire control radar (FCR) and a nose-mounted modernized target acquisition designation sight/pilot night vision sensor (MTADS/PNVS). The aircraft displays (figure 2) include two MPDs in each cockpit, the MTADS electronic display and control in the CPG station, and the integrated helmet and display sight system. The aircraft has a flight control system with a fully articulated, four-bladed main rotor system. The flight control system consists of conventional cockpit controls: cyclic, collective, and pedals connected mechanically to hydromechanical actuators for the main and tail rotors; a limited authority automatic stabilization system; and an electrically actuated stabilator.

Figure 2. Depiction of VUIT-2 for the CPG.

1.3 Assessment Procedure Overview

The workload simulation consisted of operational missions conducted by Apache aircrews in the AH-64D Risk and Cost Reduction Simulator (RACRS). The simulator was modified to represent the UAS Level II functionality to the maximum extent practicable given the maturity of the Apache Block II design.

Pilots received two days of training prior to the beginning of the assessment. The training consisted of classroom instruction and hands-on flight training in the RACRS. The pilots flew the same types of missions during training that they later flew during the record trials. The mission scenario was based on a battlefield environment simulating southwest Asia. Each successive mission increased in difficulty in order to impose progressively greater workload on the pilots. The aircrews performed specific Aircrew Training Manual (ATM) tasks during each mission. Each ATM task had prescribed conditions and standards to which both crewmembers had to perform to help ensure mission accomplishment. The aircrews also conducted missions without VUIT-2 to establish a baseline for comparing workload during non-UAS missions to workload during UAS missions.

During the formal evaluation, the aircrews performed Air Escort missions. The mission scenarios were developed by the TRADOC System Manager, Reconnaissance Attack (TSM RA) office, Fort Rucker, AL. The scenarios were developed in accordance with established aircraft tactics, techniques, and procedures (TTP).

The pilots completed the Simulator Sickness Questionnaire (SSQ) before and after each flight. They completed the Bedford Workload Rating Scale (BWRS), Situation Awareness Rating Technique (SART), and the UAS-Crewstation Interface (UCI) questionnaire after each mission. During each mission, the CPG wore an eye tracker. The eye tracker was used to assess pilot visual workload. In addition to the pilot data, subject matter experts (SMEs) were used to provide an independent assessment of aircrew workload, SA, and mission success. The SMEs completed an aircrew workload, SA, and mission success survey after each mission. After all three aircrews completed the mission and surveys, they participated in a mission debriefing and after-action review (AAR).

During the simulation, aircrew actions within the cockpit were recorded for post-test analysis. Video recordings of each crewstation and all displays were kept as a permanent record. Log files recorded all button and switch activations and recorded which MPD display was selected on each of the MPDs during the test.

1.4 Apache RACRS Cockpits

The RACRS cockpits consisted of high fidelity aircraft flight controls and displays (figures 3 and 4). The CPG utilized the TADS Electronic Display and Control (TEDAC) grips to control Apache sensors characteristics such as selecting sensors, field of view, azimuth, elevation, gain, and level. These controls were also selectable for adjustment of the UAS sensor. The TEDAC and MPD displays were used to monitor the sensor view from the Apache and/or the UAS.

Figure 3. Apache RACRS simulator (Camber Corp).

Figure 4. Apache RACRS CPG cockpit (Camber Corp).

1.5 OneSAF (One Semi-Automated Forces)

The OneSAF simulation provided the ability to generate threats/targets on the battlefield. Scenarios were developed that incorporated the detection, identification, and acquisition of simulated targets. OneSAF produced outputs on the distributed information system (DIS) network enabling all attached simulations to receive and display the entities.

1.6 UAS Control Station

A stand-alone workstation (figure 5) was developed to allow a UAS operator to independently fly a UAS during the scenarios. This was a desktop computer with a visual system representing the same terrain location as the Apache simulation. A commercial joystick and keyboard provided user input for UAS control. The operator was linked with the Apache crew via audio communications using the existing lab intercom. The UAS positional information was output onto the DIS network, allowing the other components to be aware of its location.

Figure 5. UAS control station.

1.7 AH-64 #2 Control Station

A stand-alone workstation (figure 6), similar to the UAS control station, was developed to allow an operator to independently fly a second AH-64 (wing man) during the scenarios. This was a desktop computer with a visual system representing the same terrain location as the Apache simulation. A commercial joystick and keyboard provided user input for the second AH-64 control. The operator was linked with the Apache crew via audio communications using the existing lab intercom. The AH-64 positional information was output onto the DIS network, allowing the other components to be aware of its location.

Figure 6. AH-64 #2 control station.

1.8   Terrain Location

The simulator visual system was configured to fly the existing Bagram, Afghanistan, visual database (figure 7). This is a geo-specific large gaming area built from satellite acquired high-resolution imagery and detailed terrain relief. It also contained ample terrain and cultural features which supported the goals of the assessment.

Figure 7. Apache RACRS Afghanistan database screenshot.

2. Method

2.1 Data Collection

Pilot workload, situational awareness, crew coordination, VUIT-2 crewstation interface, switch actuations, simulator sickness, visual gaze and dwell times (head-eye tracker), audio-video, and TTP data were collected and analyzed. These areas were assessed to determine if (1) pilot workload was tolerable when interacting with an UAS, (2) pilot workload in the AH-64D is higher, lower, or comparable to pilot workload when not interacting with an UAS, (3) pilots have adequate SA when interacting with the UAS, (4) the UAS control interface is easy to understand and navigate, and (5) pilots experienced simulator sickness symptoms. The data were being used to recommend design improvements to the UAS menu system, training, and associated switchology and to refine TTPs.

2.2 Pre- and Post-Trial Questionnaires

ARL HRED administered a series of questionnaires as part of the workload assessment. The questionnaires were:

* Demographics

* Simulator Sickness Questionnaire (SSQ)

* Workload (Bedford Workload Rating Scale)

* Situational Awareness (Situational Awareness Rating Technique)

* UAS Crewstation Interface (UCI)

* Subject Matter Expert (SME) Ratings

2.3 Demographics

A demographics questionnaire was used to collect basic information on each pilot's experience and flight qualifications. The demographic data documented the range of pilot experience levels and qualifications.

2.4 Workload

A common definition of pilot workload is "the integrated mental and physical effort required to satisfy the perceived demands of a specified flight task" (Roscoe, 1985). It is important to assess pilot workload because mission accomplishment is related to the mental and physical ability of the crew to effectively perform their flight and mission tasks. If pilots experience high workload when they perform flight and mission tasks (e.g., control UASs), the tasks may be performed ineffectively or abandoned.

2.4.1 Bedford Workload Rating Scale (BWRS)

To estimate the level of workload needed to control the UAS, the pilots completed the BWRS immediately after each mission. The pilots rated the workload needed to perform several UAS, flight, and mission tasks. This provided an overall assessment of the workload required to perform the missions.

The BWRS has been used extensively by the military, civil, and commercial aviation communities for estimating pilot workload (Roscoe and Ellis, 1990). It requires pilots to rate the level of workload associated with a task based on the amount of spare capacity they feel they have to perform additional tasks. Spare workload capacity is an important commodity for pilots because they are often required to perform several tasks concurrently. For example, pilots must often perform flight tasks and navigation tasks, and monitor radios within the same time interval. Mission performance is reduced if pilots are task saturated and have little or no spare capacity to perform other tasks. Design of the UCI should help ensure that pilots can maintain adequate spare workload capacity while they control UASs and perform other flight and mission tasks.

2.5   Situation Awareness (SA)

SA can be defined as the pilot's mental model of the current state of the flight and mission environment. A formal definition (Endsley, 1988) is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." It is important to assess SA because it has a direct impact on pilot performance. Good SA increases the probability of good decisions and good performance by pilots. The workload levels that pilots experience during a mission affects their SA. As pilot workload levels increase, their SA often decreases. Design of the crewstation and UAS UCI should ensure that pilots are able to maintain consistently high levels of SA while they control the UAS and perform other flight and mission tasks.

2.5.1 Situation Awareness Rating Technique (SART)

To estimate the level of SA that they experienced during missions, the pilots completed the SART scale after each mission. The SART was developed as an evaluation tool for design of aircrew systems (Taylor, 1989) and is composed of three subscales. The subscales are Understanding (U), Demand (D), and Supply (S). Taylor proposed that SA is dependent on the pilot's U (e.g., quality of information they receive), and the difference between the D (e.g., complexity of mission) on the pilot's resources and the pilot's S (e.g., ability to concentrate). When D exceeds S, there is a negative effect on U and an overall reduction of SA. The formula $SA = U - (D - S)$ is used to derive the overall SART score. The SART is one of the most thoroughly tested rating scales for estimating SA (Endsley, 2000).

2.6 UAS Crewstation Interface (UCI)

The UCI impacts crew workload and SA during a mission. A UCI that is designed to augment the cognitive and physical abilities of crews will minimize workload, enhance SA, and contribute to successful mission performance. To assess the UCI, the pilots reported any problems that contributed to high workload and low SA at the end of each mission. They also completed a lengthy questionnaire at the end of their final mission. The questionnaire addressed usability characteristics of the UCI.

2.7 Simulator Sickness Questionnaire (SSQ)

The SSQ was used to assess any problems with simulator sickness in the simulator. Any discomfort felt by the participants can adversely affect performance and how they perceive their levels of workload and SA. The SSQ helped determine if the visual effects of the simulator are a possible contributor to high workload and SA, rather than the UAS aircrew interface design.

Simulator sickness has been defined as a condition in which pilots suffer physiological discomfort in the simulator, but not while flying the actual aircraft (Kennedy et al., 1989). It is generally believed that simulator sickness is caused by a mismatch between the sensory information (e.g., acceleration cues) presented by the simulator and the sensory information presented by the primary aircraft that the pilot operates. When the sensory information presented by the simulator does not match the aircraft, the pilot's nervous system reacts adversely to the sensory mismatch and the pilot begins to experience discomfort. Characteristics of simulator sickness include nausea, dizziness, drowsiness, and several other symptoms (Kennedy et al., 1989). It is important to assess simulator sickness because the discomfort felt by pilots can be distracting. Pilot distraction is one of the operational consequences of simulator sickness listed by Crowley (1987). If pilots are distracted by the discomfort they feel during missions, their performance is likely to suffer. Additionally, the discomfort could influence the perceived levels of workload and SA that the pilots experience during a mission.

The SSQ (Kennedy et al., 1993) is a checklist of 16 symptoms. The 16 symptoms are categorized into three subscales. The subscales are Oculomotor (e.g., eyestrain, difficulty focusing, blurred vision), Disorientation (e.g., dizziness, vertigo), and Nausea (e.g., nausea, increased salivation, burping). The three subscales are combined to produce a Total Severity score. The Total Severity score is an indicator of the overall discomfort that the pilots experienced during the mission.

2.8 Switch Actuations

The RACRS was instrumented to log switch actuations to help determine whether there were tasks (e.g., UAS menu navigation) that need to be streamlined because of excessive switch manipulation.

2.9   Audio-Video Collection

Audio, video, and digital photography data collection was recorded during the simulation. Video cameras were used in the front seat and back seat of the RACRS during the trials to record pilot actions. All voice communications that occurred over the interphone communications system (ICS) were recorded and dubbed into the video recordings.

2.10 After-Action Reviews (AARs)

Daily AARs were conducted by the AH-64D Product Manager's Office (PMO) to help analyze workload, SA, and document TTP insights about the optimal employment of UASs.

2.11 Subject Matter Experts (SMEs)

SMEs observed each mission and rated crew workload, crew SA, crew coordination, and mission success. The two SMEs were both CW4 Apache pilots, and each had over 3000 hours of flight experience. The SMEs were familiar with UAS Concept of Operations (CONOPS). The SMEs provided an independent assessment of the workload and SA levels experienced by the crews. They helped identify whether problems with crew workload or crew SA contributed to lack of mission success. SME personnel observed the missions using a suite of monitors that showed all crewstation displays in the RACRS. They also listened to all audio communications between crewmembers, aircraft, ground control station, ground commander, and the tactical operations center during the missions. Several large displays provided real-time status of the location of the aircraft, UAS, friendly forces, and enemy forces to the SMEs.

2.12 Evaluation Design

While the evaluation was operational in nature rather than experimental, multiple variables were controlled in order to maximize the validity of the conclusions regarding the areas of evaluation. Table 1 summarizes the variables that were controlled during the simulation.

Table 1. Variables that were controlled during the simulation.

Factor	Control	Conditions
Mission	Constant	Air Assault
Flight profile	Tactically varied	Nap of the Earth (NOE), contour
Light conditions	Constant	Day
Scenario	Constant	Southwest Asia
Crew	Constant	Maximize crew familiarity
Seat position	Varied	Front, back
Flight uniform	Constant	Air Warrior Gen 3 combat-basic

3. Instrumentation

3.1   Switch Actuations

When initiated, the data collection software collected switch actuations at a 10 Hz rate. The collected data were time-stamped and written to a comma-delimited log file. The log file was then post-processed to an Excel spreadsheet format. The data collection software provided an interface to allow the operator to initiate and cease collection during an executed run.

3.2   Overhead Cockpit Cameras

An overhead camera was mounted in the front seat and a small camera was mounted on the glareshield in the back seat to record pilot actions. This aided in determining what the pilots were doing during different phases of the mission. The cameras had a time stamp added so it could be compared with other data collection material.

3.3   Head and Eye Tracker System

A head-eye tracking system from Applied Science Laboratories (ASL) was used to measure visual gaze and dwell times, and to help assess visual workload of the pilot (CPG) who controlled the UAS. Data obtained via the eye tracker helped determine if pilots were required to spend too much time looking at the crewstation displays to perform tasks. Data provided by the eye tracker was summarized in a graphical format. The format depicts the amount of time that each pilot spent looking at the crewstation displays and controls vs. the out-the-window visual scene. The ASL 501 head-eye tracker (figure 8) has been used extensively by the military and industry and presents no known health hazards to the wearer. The system was mounted onto the pilot's flight helmet (front seat only) via the Night Vision Goggle (NVG) mount. Head-eye tracker results complemented the questionnaire results and provide an increased understanding of crewstation workload and UCI.

3.4   Data Analysis, Limitations, and Pilot Demographics

3.4.1 Data Analysis

Pilot responses to the BWRS, SART, SSQ, and UCI questionnaires were analyzed with means and percentages. Their responses to the BWRS, SART, and SSQ were further analyzed with the Wilcoxon Signed Rank Test (WSRT) to compare the ratings between the CPG and pilot and between ratings for the VUIT-2 missions vs. non-VUIT-2 missions (MTADS only) to determine if the differences were statistically significant at $p = 0.05$.

Figure 8. Eye tracker, pupil/camera monitors, and control panel interface.

The eye tracker data were summarized by calculating the total percentage of fixations that occurred for the different areas of interest (AOI). Six AOIs were created for the CPG: right MPD, left MPD, TEDAC, keyboard, and kneeboard. Visual gaze and dwell times were also recorded for out-the-window. A final category, called "Other", captured eye fixations not focused on a specific AOI.

3.4.2 Evaluation Limitations

The primary limitations included the small sample size of pilots ($\underline{N}$=8) who participated in the crewstation simulation assessment, the limited training they received (two days), and mix of AH-64D software versions in the RACRS.

These limitations are typical when constrained by time and funding, and when replicating a complex aviation system in a simulator. However, the information and data listed in the Results and Conclustion sections of this report should be interpreted based on these limitations. Additional data should be collected during future simulations and tests to augment and expand the findings contained in this report.

3.4.3 Participants

Eight AH-64D pilots participated in the assessment. Six pilots were assigned to the 3-3 Aviation Regiment, Fort Stewart, GA; one pilot was assigned to the Directorate of Evaluation and Standardization, Fort Rucker, AL; and one pilot was assigned to the AH-64D Apache Longbow Program Management Office, Redstone Arsenal, AL. All pilots held the rank of warrant officer (CW2 = 2 pilots, CW3 = 2 pilots, CW4 = 4 pilots). Five pilots were Flight Activity Category

(FAC) 1, two pilots were FAC 2, and one pilot was FAC 3. Seven pilots were Readiness Level (RL) 1 and one pilot was RL 3. They represented a broad range of experience with total flight hours from 500 to 3800 hours. The pilot demographics are listed in table 2.

Table 2. Pilot demographics (N = 8).

Summary of Demographic Characteristics	Age (yrs)	Flight Hours in AH-64D	Total Flight Hours in Army Aircraft
Mean	37	1050	2428
Median	37	1300	2525
Range	29–43	150–1700	500–3800

4. Results

4.1 Crew Workload

4.1.1 Average Bedford Workload Ratings for Flight and Mission Tasks

The average overall Bedford workload rating for VUIT-2 missions was 3.3 for the CPG and 2.6 for the pilot (PI) (figure 9). These ratings indicate that the CPGs and PIs typically felt that workload was tolerable for the tasks, and they had enough spare mental capacity for all desirable additional tasks. The difference in workload ratings between the CPG and PI was statistically significant (WSRT, $Z = -4.109$, $p < 0.01$). This suggests that the pilots firmly believed that workload levels were somewhat higher for the CPG than the PI during most missions.
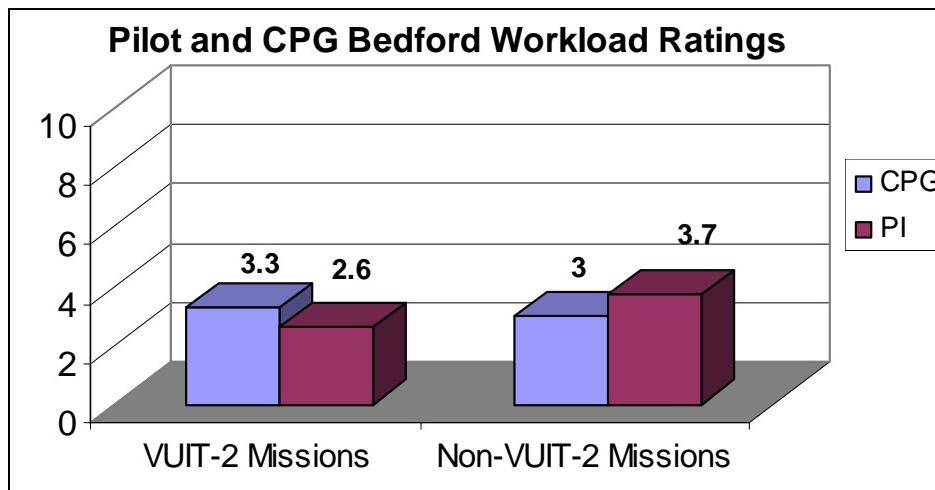
Figure 9. PI and CPG workload ratings.

The overall Bedford workload rating for the non-VUIT-2 missions was 3.0 for the CPG. This rating indicates that the CPGs typically believed that workload was tolerable, and they had enough spare mental capacity for all desirable additional tasks. The overall Bedford workload rating for the non-VUIT-2 missions was 3.7 for the PI. This rating indicates that the PIs typically believed that workload was tolerable, but they had insufficient spare capacity for easy attention to additional tasks. The difference in workload ratings between the CPG and PI was not statistically significant (WSRT, $Z = -1.684$, $p = 0.09$). This suggests that pilots perceived that workload levels were comparable for the CPG and the PI during most missions. The differences in workload ratings between VUIT-2 missions and non-VUIT-2 missions was not statistically significant for the CPG (WSRT, $Z = -0.674$, $p = 0.500$), nor statistically significant for the PI (WSRT, $Z = -0.502$, $p = 0.616$). The majority of pilots commented that the workload levels they experienced during VUIT-2 missions were comparable to workload levels they experienced during missions using only the MTADS. They reported that having to manage an additional sensor (UAS sensor) increased their overall task workload, but the SA provided by the UAS sensor typically decreased the workload required to detect and engage targets. They stated that (1) it was easier for them to detect and engage targets using the UAS sensor because of the steep visual aspect angle ('God's Eye' view) that the UAS sensor provided, compared to the shallower visual aspect angle that the MTADS typically provides during missions, (2) the SA provided by the UAS sensor reduced the time required to detect and engage targets, and (3) while they had more tasks to complete because of the additional sensor, they had more time to complete target detection and engagement tasks because of the greater stand-off range that the UAS sensor provided vs. the stand-off range that the MTADS provides during missions.

4.1.2 CPG Task Shedding

The CPGs reported that there were very few tasks that, due to high mission workload, they had to ask the PIs to perform. ARL personnel observed only a few instances when the CPG asked the PI to perform a task because he was experiencing high workload. However, the CPGs occasionally shed tasks such as responding to radio calls. There was one instance, due to high mission workload, when the CPG was unable to acquire a target and perform normal engagement tasks. In this instance, the PI utilized the 30-mm gun to engage a target because the aircraft was in close range to the threat.

4.1.3 SME Ratings of Aircrew Coordination

The SMEs provided ratings (figure 10) of how well the crews performed aircrew coordination tasks (e.g., positive communication) per Training Circular 1-210. The SMEs rated aircrew coordination during VUIT-2 missions as 'Excellent' (15%), 'Good' (31%), or 'Average' (54%). The SMEs rated aircrew coordination during non-VUIT-2 missions as 'Excellent' (17%), 'Good' (33%), or 'Average' (50%).

SME Ratings of Aircrew Coordination
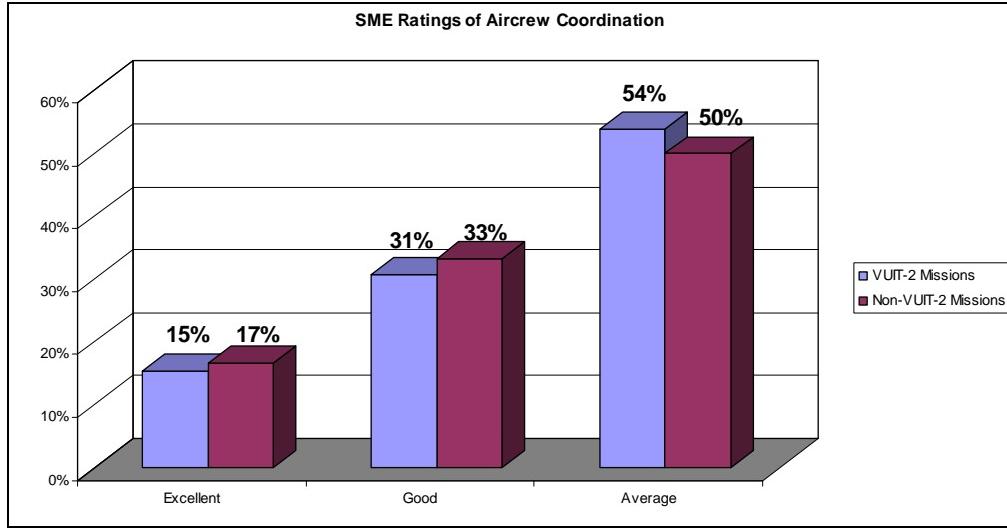
Figure 10. SME ratings for PI and CPG aircrew coordination.

4.1.4 SME Workload Ratings

SMEs provided an overall Bedford workload rating for each mission that they observed. The average SME Bedford workload rating (figure 11) was 3.9 for the CPG and 2.5 for the PI during the VUIT-2 missions. The average SME Bedford workload rating was 3.3 for the CPG and 4.2 for the PI during the non-VUIT-2 missions. These ratings indicate that the SMEs believed that (1) workload was tolerable for the CPG and PI during VUIT-2 missions, but the CPG had insufficient spare capacity for easy attention to additional tasks; and (2) workload was tolerable for the CPG and PI during non-VUIT-2 missions, but the PI had insufficient spare capacity for easy attention to additional tasks. The difference in SME workload ratings between the CPG and PI was statistically significant for the VUIT-2 missions (WSRT, $Z = -2.555$, $p = 0.011$), but not statistically significant for the non-VUIT-2 missions (WSRT, $Z = -0.447$, $p = 0.655$).

SME Bedford Workload Ratings
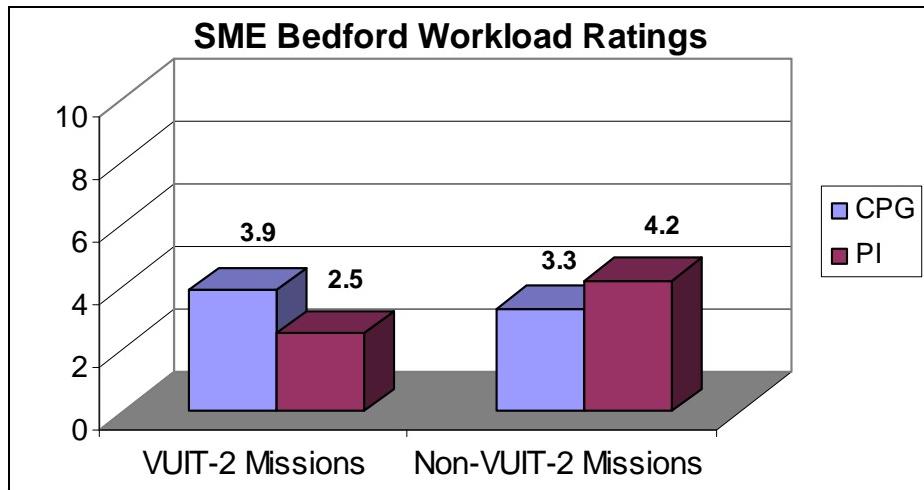
Figure 11. SME Bedford workload ratings.

In previous simulations and operational tests that ARL has helped conduct, SMEs have typically rated pilot workload higher than the ratings provided by the pilots. SMEs have more information (e.g., location of all threat and friendly vehicles) available to them to assess pilot performance and workload than the information that the pilots have available to them. SMEs are often more aware of pilot mistakes (that may be attributable to workload) than the pilots. The additional information that the SMEs have likely results in a more critical assessment of pilot performance and workload.

4.1.5 Visual Workload

Figure 12 shows the average percentage of time that the CPGs were visually focused on each AOI during the VUIT-2 missions. The CPGs were visually focused on the right MPD for 13% of the time during missions. They were visually focused on the left MPD for 17% of the time and the TEDAC (MTADS sensor) for 48%. It is interesting to note that the CPGs typically spent only 3% of the time visually focused out-the-window during missions. Figure 13 shows the average percentage of time that the CPGs were visually focused on each AOI during the non-VUIT-2 missions. The CPGs were visually focused on the right MPD for 10% of the time during missions. They were visually focused on the left MPD for 4% of the time and the TEDAC for 73%.
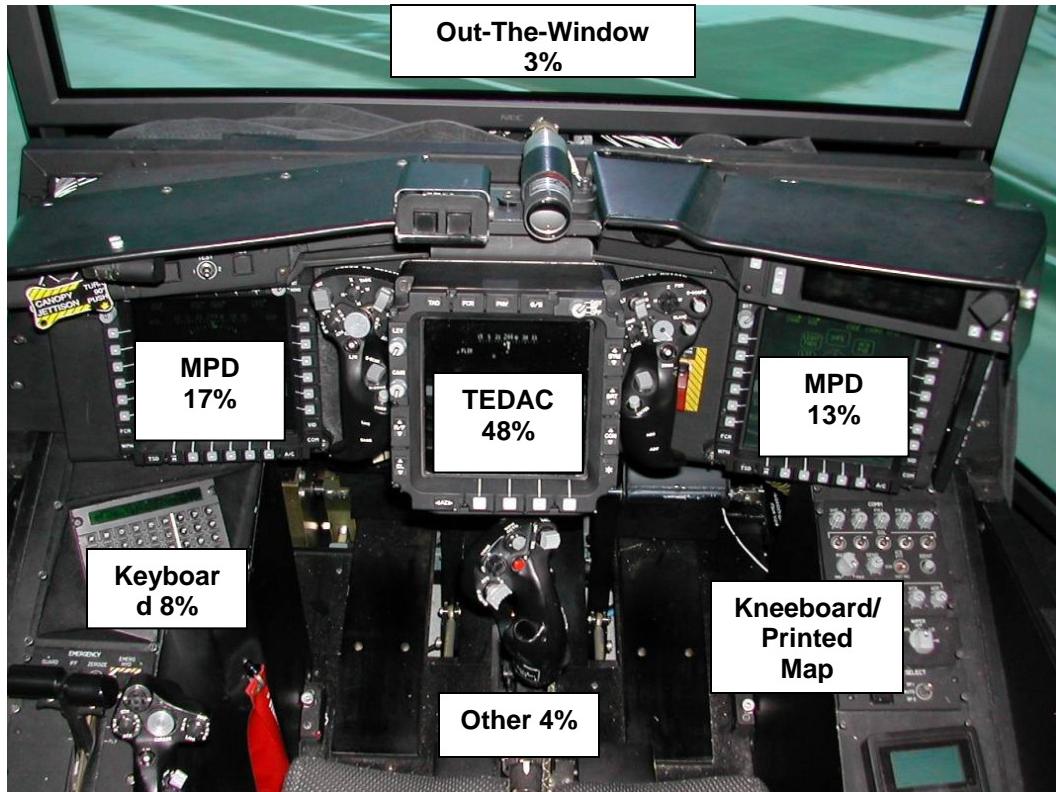
Figure 12. CPG visual gaze and dwell times during VUIT-2 missions.
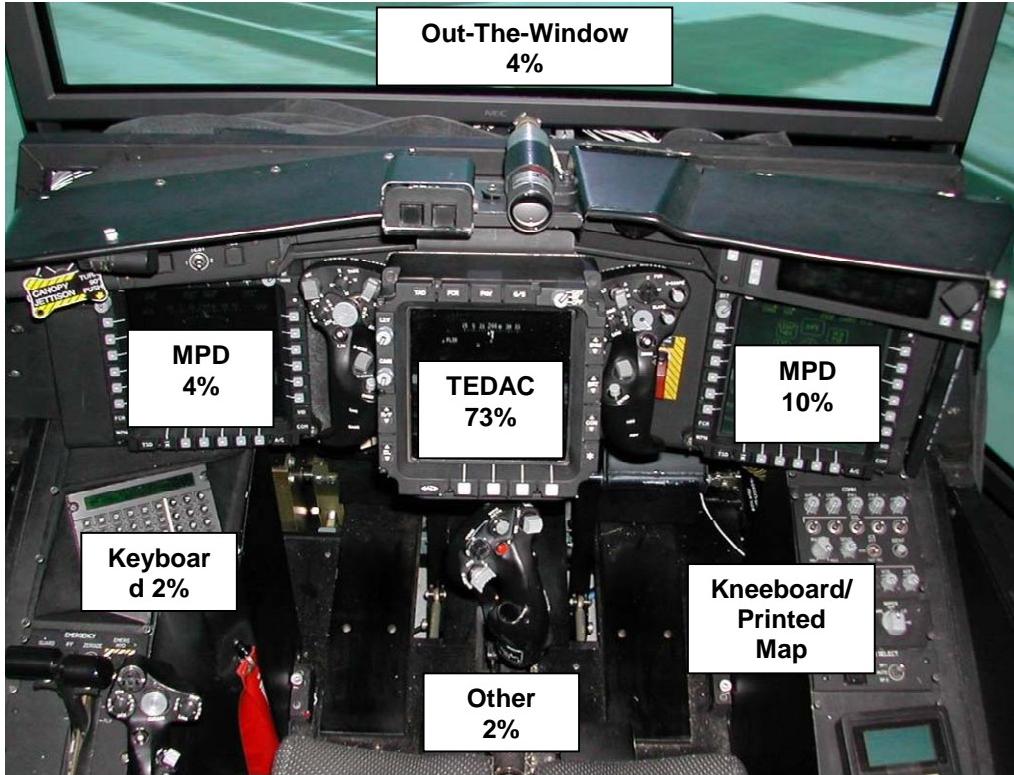
Figure 13. CPG visual gaze and dwell times during non-VUIT-2 missions.

A small camera was mounted on the glareshield in the rear cockpit so that ARL personnel could observe how much time the PIs spent visually focused inside versus outside the aircraft. ARL personnel observed that the PIs were visually focused outside the aircraft approximately 75% of the time and inside 25% of the time during the VUIT-2 missions and non-VUIT-2 missions (figure 14). The PIs confirmed the observations made by ARL personnel during post-mission discussions.

During the VUIT-2 missions and non-VUIT-2 missions, the CPGs were not able to maintain visual focus outside the aircraft to assist with navigation (e.g., identification of terrain features), local security, terrain flight, etc. For 96+% of the time, the CPGs were visually focused inside the aircraft performing (mostly) target detection and engagement tasks. It should be cautioned that the simulation was conducted with a small sample size of pilots, the pilots did not get all of the peripheral visual cues that they would in an aircraft, and pilots knew that they would not suffer harm if they crashed the simulator.
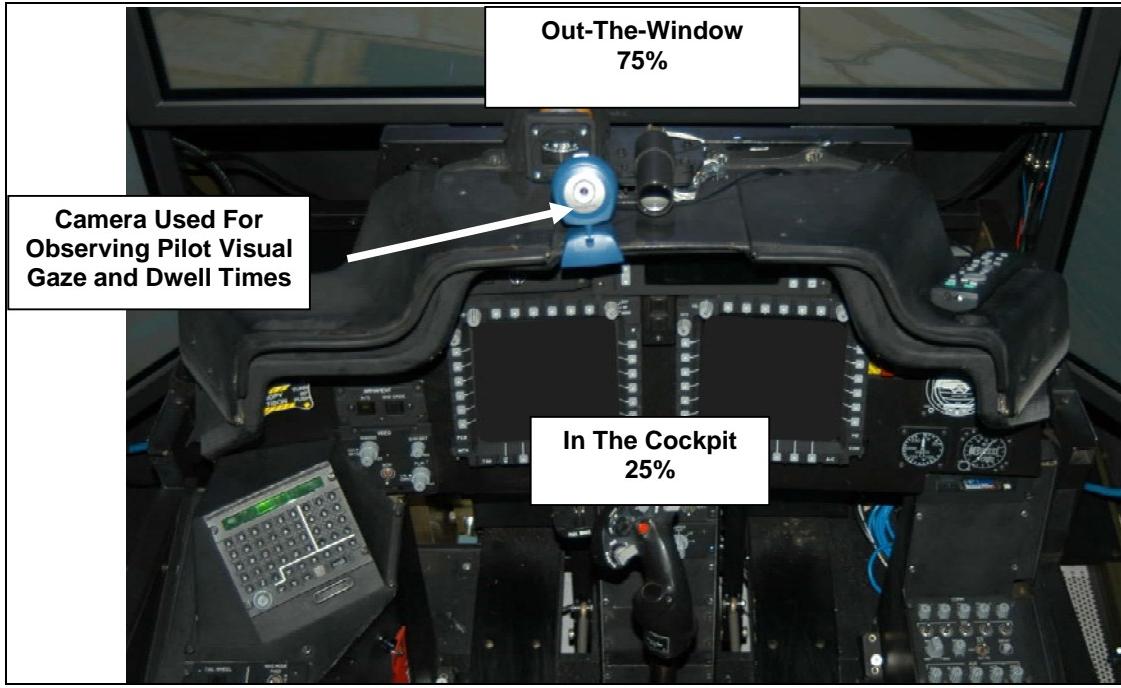
Figure 14. PI visual dwell times estimates for all missions.

4.1.6 Comparison of Eye Tracker Data

Table 3 shows a comparison of AH-64D, Armed Recon Helicopter (ARH) and UH-60M eye tracker data for Visual Flight Rules (VFR) flight during various aircraft simulations. These simulations were observed by ARL-HRED personnel and include workload assessments, limited user tests, and crewstation evaluations. While the aircraft, missions, training and personnel experience levels were different for each simulation evaluation, it is interesting to note the differences in visual gaze and dwell times for each evaluation.

Table 3. Comparison of eye tracker results for AH-64D, UH-60M, and ARH-70 simulations.

	AH-64D/VUIT-2 Workload Assessment		AH-64D/UAS Workload Assessment (non-VUIT-2)		AH-64D Workload Assessment (Block III)		UH-60M Limited User Test		ARH-70 HFE-CAAS Evaluation	
	Flying Pilot[a] (%)	CPG (%)	Flying Pilot[a] (%)	Non Flying Pilot (%)	Flying Pilot[a] (%)	Non Flying Pilot (%)	Flying Pilot (%)	Non Flying Pilot (%)	Flying Pilot (%)	Non Flying Pilot (%)
Outside	75	3	75	4	75	6	86	28	61	7
Inside	25	97	25	96	25	94	14	72	39	93

[a]Estimate from watching PI gaze and dwell times with video camera during missions (non-eye tracker).

4.2   Crew Situation Awareness

4.2.1 Situation Awareness Ratings

The overall SART scores provided by the pilots were 19.0 for the CPG and 21.3 for the PI (figure 15) during the VUIT-2 missions. These scores indicate that the CPG and PI felt they had moderate levels of overall SA during the missions. The difference between SART scores for the CPG and PI was not statistically significant (WSRT, $Z = –0.491$, $p = 0.624$). The SART scores for non-VUIT-2 missions were 19.6 for the CPG and 18.0 for the PI (figure 15). The difference between SART scores for the CPG and PI was not statistically significant for the non-VUIT-2 missions (WSRT, $Z = –1.633$, $p = 0.102$). The difference between SART scores for the VUIT-2 missions and non-VUIT-2 missions was not statistically significant for the CPG (WSRT, $Z = –0.535$, $p = 0.593$) or for the PI (WSRT, $Z = –1.342$, $p = 0.180$). The pilots stated that they had higher SA during VUIT-2 missions (vs. non-VUIT-2) mostly because of the "God's Eye" view that the UAS sensor video provided during missions. The UAS sensor video also gave the pilots good SA earlier in the mission (vs. non-VUIT-2 missions) because they often received the video prior to (or just after) take-off of their aircraft.
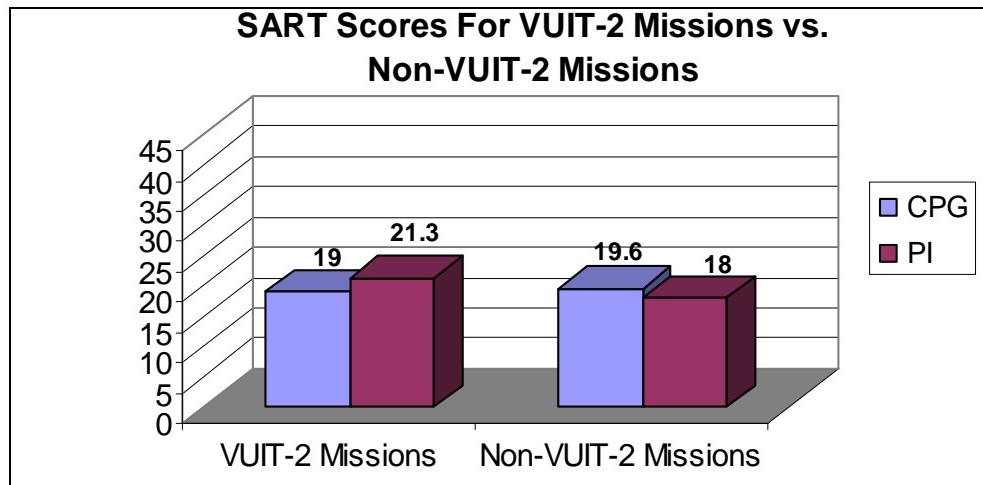
Figure 15. Overall SART scores for PI and CPG.

The pilots reported that they had moderate levels of SA of most of the battlefield elements (appendix C) during both VUIT-2 and non-VUIT-2 missions. The battlefield elements included location of enemy and friendly units, location of own ship, location of cultural features (e.g., bridges), and route information (e.g., waypoints). However, there were instances during VUIT-2 missions and non-VUIT-2 missions when the aircraft flew near the target(s) and missiles were fired outside of the aircraft/UAS constraints. This was likely caused by the lack of extensive training and experience with the UAS and the need for improved cueing symbology to help pilots understand where both their aircraft and the UAS are located in reference to the targets.

4.2.2 SME Situation Awareness Ratings

The SMEs provided an independent assessment of aircrew SA based on the scale shown in table 4. The SMEs mean SA rating for aircrews during VUIT-2 missions was 2.08. The SMEs mean SA rating for non-VUIT-2 missions was 3.0. This indicates that the SMEs perceived that the aircrews typically had adequate levels of SA during the VUIT-2 and non-VUIT-2 missions.

Table 4. SME situation awareness rating.

	SME Situation Awareness Ratings
1	Crew was consistently aware of all entities on the battlefield as well as the status of their aircraft.
2	Crew was aware of the battlefield and their own ship with minor or insignificant variation between perception and reality.
3	Crew was aware of the battlefield and their own ship. Variation between reality and perception did not significantly impact mission success.
4	SA needs improvement. Lack of SA had some negative effect on the success of the mission.
5	Lack of SA caused mission failure.

Mean Rating
(VUIT-2)
2.08
(SD = 0.95)

Mean Rating
(Non-VUIT-2)
3.00
(SD = 1.55)

The SMEs noted that there were instances when the aircraft flew near the target(s) and missiles were fired outside of the aircraft/UAS constraints. During the non-VUIT-2 missions, crew members occasionally had difficulty identifying friendly targets using the MTADS. The misidentification of targets resulted in fratricide and increased workload while both pilots tried to determine whether the target was friendly.

4.2.3 SME Ratings of Mission Success and Mission Objectives

At the end of each mission, SMEs rated whether the mission was a success or failure. The criteria that the SMEs used to rate mission success or failure was whether the aircrew completed most or all of their mission objectives and did not get shot down or crash. The SMEs rated all of the VUIT-2 missions as "successful" (figure 16). The SMEs rated 17% of the non-VUIT-2 missions as failures or incomplete. This was due to a fratricide resulting from a misidentification of a friendly entity. They also rated whether the aircrew completed their mission objectives. The mission objectives were given to the pilots during the pre-mission brief and are listed in appendix G. The SMEs believed that the aircrews completed their objectives for 100% of the VUIT-2 missions and 83% of the non-VUIT-2 missions.
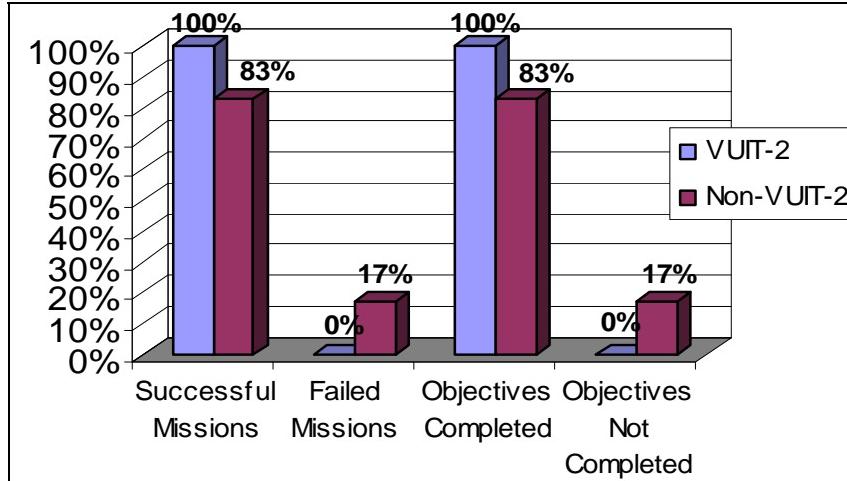
Figure 16. SME ratings of mission success and mission objectives.

4.3 UAS Crewstation Interface (UCI)

Most pilots reported that the UCI was usable, but needed improvements to enhance overall effectiveness. The pilots reported some difficulty operating the buttons on the VUIT-2 keypad, and that a backspace or clear button was needed to reduce workload and the amount of time needed during data entry procedures to correct any errors. Most CPGs reported that the UCI contributed to higher workload during the missions due to difficult data entry procedures and map symbology. The CPGs also occasionally forgot the steps required for operating the UAS interface during set up and target tracking. All CPGs reported that with more experience and training, they would be able to remember the steps required for operating the UAS interface. CPGs reported that the map symbology for the UAS was difficult to read and interpret. Suggestions were made to change the color and scale of the icons, along with modifying the manner in which the direction of the UAS sensor is displayed on the map. Several improvements that the pilots recommended be made to the UCI to increase usability and decrease workload, and the time required to complete tasks, are listed in appendix E.

4.4 Switch Actuations

Switch actuations were recorded to help determine whether there were CPG tasks (e.g., UAS menu navigation) that need to be streamlined because of excessive switch actuations. The switch actuations are summarized in appendix F. The CPGs made an average of 316 switch actuations per UAS mission. The CPGs made an average of 53 VUIT-2 specific button presses per mission. The total average combined number of button presses for VUIT-2 missions was 369. This equates to approximately 7–8 switch actuations per minute, or one switch actuation per 8 s for each mission. The switch actuations were often clumped together within specific time intervals. Non-VUIT-2 missions averaged 525 button presses per mission. This equates to approximately 11 button presses per minute, or one switch actuation every 5 s interval for each mission. The rise in the number of switch actuations from VUIT-2 missions to non-VUIT-2 missions was mostly due to the increased use of the MTADS FOV switch. The pilots were forced to use the

MTADS to search for targets rather than the UAS video feed, causing an increase in the amount of button presses required to search and locate targets. The switches that were actuated most often by the CPG during both VUIT-2 and non-VUIT-2 missions were the MTADS FOV select switch, right-hand grip slave select switch, left-hand grip tracker switch, right-hand grip laser trigger, right MPD bezel buttons, and the weapon trigger. The pilots reported that they did not think that the number of switch actuations per mission was excessive. Many of the switch actuations were momentary actuations of the MTADS FOV select switch and right-hand grip slave select switch.

Table 5 summarizes the number of MPD page changes per mission. The average number of right and left MPD page changes was 50 for the CPG and 48 for the PI per VUIT-2 mission. The average number of right and left MPD page changes during non-VUIT-2 missions was 39 for the CPG and 24 for the PI (table 6). The Tactical Situation Display (TSD) and Tactical Common Data Link (TCDL) pages were the pages most often displayed by the CPG and PI during missions.

Table 5. MPD page changes during the VUIT-2 missions.

No. of Page Changes per Mission (VUIT-2 Missions)				
Mission	CPG (Right MPD)	CPG (Left MPD)	Pilot (Right MPD)	Pilot (Left MPD)
1	59	47	40	42
2	34	20	9	76
3	2	35	27	8
4	40	2	14	30
5	29	26	11	20
6	28	0	0	6
7	24	15	28	44
8	31	1	13	14
Average	30.875	18.25	17.75	30
Std. dev.	15.93	17.22	12.87	23.52
Min	2	0	0	6
Max	59	47	40	76

Table 6. MPD page changes during the non-VUIT-2 missions.

No. of Page Changes per Mission(Non-VUIT-2 Missions)				
Mission	CPG (Right MPD)	CPG (Left MPD)	Pilot (Right MPD)	Pilot (Left MPD)
9	22	18	5	21
10	21	2	8	42
11	14	37	19	13
12	24	16	11	0
Average	20.25	18.25	10.75	19
Std. dev.	4.35	14.38	6.02	17.61
Min	14	2	5	0
Max	24	37	19	42

4.5   Top Improvements Recommended by Pilots

The pilots recommended that several improvements be made to the UCI and UAS to increase usability and decrease workload and the time required to complete tasks. Following are the most significant improvements that the pilots recommended be made to improve UAS employment. Examples for each improvement are listed in appendix E.

- Need the ability to record MTADS and VUIT-2 video and audio communications without switching one recorder off.

- UAV icon colors should be changed to make them more easily recognizable while scanning.

- Map needs increased fidelity and proper scaling of icons and symbology.

- UAV icons should be integrated into the current TSD page.

- Improve functionality of the VUIT-2 keypad, to include a backspace function and enter key.

- Need battlefield graphics to aid with remote laser designation during target engagements.

4.6   Simulator Sickness

Pilots reported that they typically experienced very mild to mild simulator sickness symptoms during the evaluation. The overall mean Total Severity (TS) score (post mission) for the pilots was 4.98 (table 7). The mean TS score for the CPGs was 7.79 and the mean TS score for the PIs was 2.18. The difference between the pre-flight SSQ and the post-flight SSQ scores for the CPG was not statistically significant (WSRT, $Z = -0.768$, $p = 0.461$). The difference between the pre-flight SSQ and the post-flight SSQ scores for the PI was also not statistically significant (WSRT, $Z = 0.000$, $p = 1.000$). Based on the categorization of simulator sickness symptoms proposed by Kennedy et al. (2002) (table 8), the pilots experienced "minimal" simulator sickness symptoms during the missions.

Table 7. Simulator sickness questionnaire (SSQ) ratings.

Condition	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
Pre-mission (CPG)	3.97	6.31	4.64	5.92
Post-mission (CPG)	3.97	7.58	9.28	7.79
Pre-mission (PI)	1.59	3.15	0	2.18
Post-mission (PI)	2.38	2.52	0	2.18
Pre-mission CPG and PI	2.78	4.73	2.32	4.05
Post-mission CPG and PI	3.18	5.05	4.64	4.98

Table 8. Categorization of simulator sickness symptoms.

SSQ Total Score	Categorization
0	No symptoms
<5	Negligible symptoms (PI)
5–10	Minimal symptoms (CPG)
10–15	Significant symptoms
15–20	Symptoms are a concern
>20	A problem simulator

Note: Categorization of symptoms based on central tendency (mean or median)
using military aviation personnel in each simulator (Kennedy, 2002).

4.7 Comparison of RACRS Simulator SSQ Scores to Other Helicopter Simulators

To assess whether the SSQ ratings provided by the pilots during the assessment were similar or different to ratings obtained in other helicopter simulators, the mean SSQ scores for the RACRS simulator were compared to the mean SSQ scores for several other helicopter simulators (table 9). The other helicopter simulators were the AH-64A (Army Research Institute, non-motion simulator), Armed Reconnaissance Helicopter (ARH-70), S-3H, CH-46E, CH-56D, CH-56F, Sikorsky RAH-66 Engineering Development Simulator (EDS), RAH-66 Comanche Portable Cockpit (CPC), and the simulator used during the UH-60M for the Early User Demo (EUD), RACRS (UAS) and Limited Early User Evaluation (LEUE). In comparison, the RACRS induced fewer simulator sickness symptoms than the other helicopter simulators listed in table 9.

Based on pilot SSQ ratings, observation by ARL HRED personnel during missions, feedback during post mission interviews, and comparison of SSQ ratings with ratings from other helicopter simulators, it is reasonable to assume that the simulator sickness symptoms the pilots experienced did not (1) cause them significant discomfort, (2) distract them during missions, or (3) contribute to an increase in perceived workload.

Table 9. Comparison of RACRS simulator SSQ ratings with other helicopter simulators.

Simulator	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
AH-64A[a]	—	—	—	25.81
ARH-70	18.02	21.48	9.28	20.15
SH-3H	14.70	20.00	12.40	18.80
RAH-66 EDS	11.84	14.98	4.54	13.25
CH-53F	7.50	10.50	7.40	10.00
RAH-66 CPC	3.29	12.94	7.89	9.80
UH-60M (LEUE)	6.36	11.81	3.09	9.15
RACRS (UAS)	9.01	7.58	4.64	8.51
UH-60M (EUD)	13.88	6.89	0	8.50
CH-53D	7.20	7.20	4.00	7.50
CH-46E	5.40	7.80	4.50	7.00
RACRS (VUIT-2)	**3.18**	**5.05**	**4.64**	**4.98**

[a]SSQ subscale data not available.

5. Conclusions

Pilots reported that they typically experienced tolerable workload when performing missions while controlling the UAS. They reported that the workload they experienced was comparable to workload they experienced during "non-VUIT-2" missions. They stated that having to interact with an additional sensor (UAS sensor) increased their overall task workload, but the SA provided by the UAS sensor decreased the workload required to detect and engage targets, and decreased overall target engagement timelines. The SMEs reported that the pilots typically experienced tolerable workload when controlling the UAS during missions, but had reduced spare workload capacity. The workload ratings provided by the pilots and SMEs were lower than the Objective and Threshold workload ratings requirements listed in the Apache Block III (AB3) Capability Development Document (CDD) (table 10).

5.1 Crew Workload

Table 10. Pilot workload requirements and ratings.

CDD Bedford Workload Rating Requirements	Pilot Bedford Workload Ratings for VUIT-2 Missions	SME Bedford Workload Ratings for VUIT-2 Missions
Objective req. – '5.0'	PI – '2.6'	PI – '2.5'
Threshold req. – '6.0'	CPG – '3.3'	CPG – '3.9'

5.2 Crew Situation Awareness

Pilots typically experienced moderate levels of SA during missions. They reported that they had high levels of SA of most of the battlefield elements (e.g., threat location) during the missions. However, there were instances when they flew near the targets and fired missiles outside of the aircraft/UAS constraints. This was likely caused by the lack of extensive training and experience with the UAS and the need for improved cueing symbology to help pilots understand where their aircraft and the UAS are located in reference to the targets. The pilots stated that they had higher SA during VUIT-2 missions (vs. non-VUIT-2 missions) mostly because of the "God's Eye" view that the UAS sensor video provided during missions. The UAS sensor video also gave the pilots good SA earlier in the mission (vs. non-VUIT-2 missions) because they often received the video prior to (or just after) take-off of their aircraft. The SMEs reported that the aircrews typically had adequate levels of SA.

5.3 Crew Coordination

The SMEs identified no significant problems with aircrew coordination during the VUIT-2 and non-VUIT-2 missions. The SMEs rated aircrew coordination during VUIT-2 missions as "Excellent" (15%), "Good" (31%), or "Average" (54%). The SMEs rated aircrew coordination during non-VUIT-2 missions as "Excellent" (17%), "Good" (33%), or "Average" (50%).

5.4 UAS-Crewstation Interface

Most pilots reported that the UCI was usable, but needed improvements to enhance overall effectiveness. They reported that they were able to appropriately operate the VUIT Interface Panel (VIP) switches and keypad to accomplish UAS mission tasks, although the current configuration was not considered the most efficient design. Pilots commented that the number of switch actuations per mission was not excessive. They also felt that the overall design of the UCI somewhat hindered them from interacting with the UAS in a timely manner, and reported that the UCI contributed to high workload during specific data entry procedures and symbology interpretation. In some instances, the buttons were considered too small to manipulate quickly, and pilots reported that remembering their appropriate functions was difficult. The functionality of the keypad also caused an increase in time and workload during some missions. All of the pilots reported that the symbology presented was difficult to understand.

The pilots recommended that several enhancements should be made to improve the VUIT-2 crewstation interface and overall operation (appendix E). The pilots commented that with several enhancements and more experience using the system, most of the increased workload and decreased efficiency could be improved.

5.5 Simulator Sickness

Pilots reported that they typically experienced very mild to mild simulator sickness symptoms during the evaluation. The simulator sickness symptoms the pilots experienced did not (1) cause them significant discomfort, (2) distract them during missions, or (3) contribute to an increase in perceived workload.

6. Recommendations

The following recommendations are made to enhance the overall effectiveness and suitability of the UAS VUIT-2 integration into the AH-64D:

- Address and incorporate the recommended improvements (as appropriate) provided by the pilots.

- Use the Crew Station Working Group to address and incorporate the recommended improvements.

- Upgrade the RACRS simulator to make it representative of the AH-64D Block 3 design to enhance future simulations.

- Continue using the RACRS to help train pilots, and refine the UCI and TTPs for the Block 2 UAS integration (VUIT).

- Maximize the amount of pilot training for future UAS evaluations.

- Use the same data collection methodology (e.g., Bedford, SART) during future simulations and tests for Apache VUIT-2 teaming. Standardizing the data collection methodology will help identify changes that work (e.g., changes that reduce workload), identify areas that still need more work, and drive continuous incremental improvements.

- Incorporate VUIT-2 capability into the Longbow Crew Trainers to aid with pilot training.

7. References

Crowley, J. S. Simulator sickness: A Problem for Army Aviation. *Aviation Space and Environmental Medicine* **1987**, *58*, 355–357.

Endsley, M. R. Design and Evaluation for Situation Awareness Enhancement. *Proceedings of the Human Factors Society 32nd Annual Meeting*, Vol. 1, 92–101, 1988.

Endsley, M. R. *Situation Awareness Analysis and Measurement*. Lawrence Erlbaum Associates: Mahwah, NJ, 2000.

Kennedy, R. S.; Drexler, J. M.; Compton, D. E.; Stanney, K. M.; Lanham, D. S.; Harm, D. L. Configural Scoring of Simulator Sickness, Cybersickness, and Space Adaptation Syndrome: Similarities and Differences. In *Virtual and Adaptive Environments: Applications, Implications, and Human Performance*; Hettinger, L. J., Haas, M. W., Eds., Mahwah, NJ: Erlbaum, 2002, pp. 247–278.

Kennedy, R. S.; Lane, N. E.; Berbaum, K. S.; Lilienthal, M. G. Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *International Journal of Aviation Psychology* **1993**, *3*, 203–220.

Kennedy, R. S.; Lilienthal, M. G.; Berbaum, B. A.; Balzley, B. A.; McCauley, M. E. Simulator sickness in U.S. Navy Flight Simulators. *Aviation Space and Environmental Medicine* **1989**, *60*, 10–16.

O'Brien, T. G.; Charlton, S. G. *Handbook of Human Factors Testing and Evaluation*; Lawrence Erlbaum Associates: Mahwah, NJ, 1996.

Roscoe, A. H. *The Airline Pilots View of Flight Deck Workload: A Preliminary Study Using a Questionnaire;* Technical Memorandum No. FS (B) 465; Royal Aircraft Establishment: Bedford, UK, 1985.

Roscoe, A. H.; Ellis, G. A. *A Subjective Rating Scale for Assessing Pilot Workload in Flight: A Decade of Practical Use*. Royal Aerospace Establishment: Bedford, UK, 1990.

Taylor, R. M. *Situational Awareness Rating Technique (SART): The Development of a Tool for Aircrew Systems Design*. Proceedings of the NATO Advisory Group on Aerospace Research and Development (AGARD) Symposium on Situational Awareness in Aerospace Operations AGARD-CP-478, 3/1 - 3/17), Neuilly Sur Seine, France: NATO – AGARD, 1989.

Appendix A. Bedford Workload Rating Scale Scores and Pilot Comments

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This appendix appears in its original form, without editorial change.

Bedford Workload Rating Scale

Workload Description	"Rating"
Workload insignificant	1
Workload low	2
Enough spare capacity for all desirable additional tasks	3

Insufficient spare capacity for easy attention to additional tasks	4
Reduced spare capacity. Additional tasks cannot be given the desired amount of attention	5
Little spare capacity: level of effort allows little attention to additional tasks	6

Very little spare capacity, but maintenance of effort in the primary tasks not in question	7
Very high workload with almost no spare capacity. Difficulty in maintaining level of effort	8
Extremely high workload. No spare capacity. Serious doubts as to ability to maintain level of effort	9

Task abandoned. Pilot unable to apply sufficient effort	10

YES

Was workload satisfactory without reduction in spare (workload) capacity?

NO

YES

Was workload tolerable for the task?

NO

YES

Was it possible to complete the task?

NO

Pilot Decisions

Flight and Mission Tasks	VUIT 2 Mission Workload Rating		Non VUIT-2 Mission Workload Rating	
Seat	**Front**	**Back**	**Front**	**Back**
Before Takeoff Checks	1.3	1.2	1.0	1.0
Observing NAI's	3.0	1.5	3.0	1.0
Target Detection	2.9	2.4	3.3	2.0
Target Acquisition	2.5	2.3	3.7	3.0
Target Engagement	2.1	2.4	2.3	2.0
Movement To Contact	2.3	2.0	3.0	1.5
Actions On Contact	2.7	2.0	2.5	2.5
Battle Damage Assessment And Reporting	1.4	1.5	2.0	1.5
Mission Change	2.3	2.2	2.0	3.0
Battle Handover	2.3	1.7	3.0	
Tactical Navigation (Contour/NOE)	2.0	1.4	1.0	1.5
Communications (TOC, Wingman)	2.1	2.0	1.5	3.0
NOE/Contour/Low Level Flight	2.3	1.4	2.0	1.0
Maintain Airspace Surveillance	3.3	2.4	2.0	3.0
VMC Flight Maneuvers	1.8	1.5	1.0	1.5
Electronically Aided Navigation	2.5	1.5	1.7	2.0
Terrain Flight Navigation	2.2	1.4	1.0	1.0
Masking and Unmasking	1.7	2.0	2.0	2.0
Evasive Maneuvers	2.3	2.0	2.0	
MTADS/PNVS Operations	2.7	1.8	2.0	1.5
Route Recon	1.7	1.4	3.0	1.5
Area Recon	1.7	1.4	3.0	1.0
Level 2 UAS Control	2.9	2.0		
Data Entry Procedures	3.6	2.0	2.3	1.0

Engage with Hellfire	1.9	2.1	1.7	1.5
Engage with 2.75 Rockets	1.5	1.5		1.0
Engage with 30mm AWS	2.3	1.3	1.7	1.0
Multi-ship Operations	2.4	1.5	2.0	2.3
Transmit Tactical Reports	2.0	1.5	2.0	2.0
Identify Major US/Allied and Threat Equipment	2.1	1.6	3.0	3.0
Information Management In The Front Seat (CPG)	3.3	-----	2.3	-----
Information Management In The Back Seat (Pilot)	-----	2.6	-----	2.3
Average Ratings for ATM Tasks	2.3	1.8	2.2	1.8
Overall Workload Rating For The Mission (Average)	3.3	2.6	3.0	3.7

Pilot Workload Comments

If you gave a workload rating of '5' or higher for any task in the UAS mission column, explain why the workload was high for the task.

Explanations as to why the pilots assigned a rating of '5' or higher for a task

(VUIT-2 Missions)

Question 1:

Target Detection and Acquisition:

- Target detection and acquisition. With VUIT you have the ability to see the target and atmosphere from a distance. W/out VUIT we depend on "most of the time" a general grid from ground units. VUIT a definite plus.

- Target detection. You know there is a target out there, but actually detecting it is frustrating. – Non UAV is frustrating but you don't know there is a target there.

- Target Detection. Enroute VUIT is a great asset in detecting targets. Once you're in the fight it's too busy for the CPG to be messing with the VUIT. It turns the pilot into truly alone and in the fight.

- Target Detection. We know there is a target there, but where in relation to our A/C and altitude.

Maintain Aircraft/Airspace Surveillance:

- Maintain A/C surveillance. A lot of heads down in the front seat in light out operations it is a big concern for obstacle avoidance.

- Maintain Airspace. Heads down entire flight, could not spare time to help clear A/C.

- Airspace Surveillance. Same as before, only one set of eyes outside and a more complex mission.

Data Entry:

- Data Entry. If you place another piece of equipment in the aircraft it requires you to enter more information, but the VUIT increases your SA 10x fold which decreases your workload.

- Data entry. Takes so much time to enter numbers, then if you mess up, no backing up, I had to restart the page.

Information Management:

- Info. Management. A lot of info quick, CPG has to prioritize what must happen first and this does not leave much spare attention to other tasks.

- Information management. Was able to keep awareness, but due to the VUIT I was having some problems maintaining the UAV location. Had to depend on the CPG for that.

- Information Management (CPG). I still spend too much time inside and not outside gathering situation awareness.

- Pilot Info Management. More complex mission and the use of VUIT-2 limits how quickly we can change from VUIT to VCR.

Communication:

- Commo. A lot more target activity and commo requirement for this type of mission.

(Non-VUIT-2 Missions)

Question 1:

Target Acquisition:

- Target acquisition. Was a little more difficult compared to a VUIT engagement. Actually PID'ing the correct target.

- TGT ACQ – due to the fact the simulator is not like the A/C.

Communication:

- Commo. More complex mission requires more communications between all members of the flight.

List any flight and/or mission tasks that you had to ask your crewmember to accomplish because your workload was too high.

 (VUIT-2 Missions)

Question 2:

- I didn't need anything to be done for me. However, sensing how busy the CPG was with the VUIT, the radios, and targeting. I took a lot of the radio traffic on as well as some engagements.

- Engagement of one target was taken over by PLT gun because of closeness to target.

- 2 Hellfire missiles lost due to lost of SA and crew coordination due to workload. Increase in workload due to both mission type and some VUIT requirements.

Appendix B. Subject Matter Expert Workload Comments

This appendix appears in its original form, without editorial change.

If you assigned a workload rating of '5' or higher for either crewmember, explain why:

(VUIT-2 Missions)

TSC WL1:

- Much better "SA" than yesterday for this crew. CPG had a much better grasp of the system.

- Good mission.

- Had to be prompted to come out of freeze on the VUIT-2. Did not use VUIT-2 map for orientation. Front seat couldn't move sensor, but was still autotracking.

- Both set up VUIT video, B/S up flight page. B/S told warlock deviation to engage ZSU.

- Crew still had difficulty operating VUIT system. Crew recorded engagement well. No reports to warlock that they were going to engage.

- Because of CPG unfamiliarity with Longbow systems, this caused greater workload when VUIT-2 capability was added. CPG saturated and having difficulty including additional tasks.

(Non-VUIT-2 Missions)
TSC WL1:
- Pilot inside helping CPG with engagement, almost allowed aircraft to descend into ground.

- Flew constantly enroute at 106%. Front seater had difficulty manipulating the MTADS auto tracker.

- Front seat was unaware that his missile and laser code did not match. ZSU engagement. 30mm was at the AZ limit. A/C heading 302 TADS heading 180.

- The crew at times had difficulty orienting their sensor and the A/C in the same direction to effectively track and engage targets.

SME Aircrew Coordination Comments:

(VUIT-2 Missions)

TSC WL2:

- Good coordination for weapons engagements.

Describe any problems that aircrews had with situation awareness:

(VUIT-2 Missions)

TSC SA:

- Engagement 1 – Good geometry/good remote shot.

- Engagement 2 – CPG intent on adding information and allowing TADS to hit symbol units. While changing between UAS video, crew was sent incorrect data causing confusion. Updated grid with wrong identifier (VD instead of WD). CPG kept up screen capture mode after inserting grid, not required and ties up MPD.

- Crew was aware of their position and the UAS position.

- Engagement 1 – Good engagement.

- Engagement 2 – Remote, good geometry for shot, target destroyed.

- Engagement 1 – Good shot. Good use of UAS.

- Engagement 2 – Good SA comparing UAS video to TADS video. Crew should be cognizant of getting too close to enemy (do not overfly target).

- Engagement 1 – CPG inserted wrong Freq. not received UAS video slowing the process. This is not he first time this CPG has inputted wrong Freq, but getting better. Both crewmembers have VUIT-2 video up all the time. Recommend using VUIT-2 video/map for orientation, especially during autonomous engagement.

- Engagement 2 – Crew read back Freq's. (good technique) good engagements.

- Good mission.

- Operator knowledge of MTADS caused confusion in cockpit. CPG should try to coordinated UAS video to TADS video instead of inserting grids. Inserting grids takes more times for engagement. CPG has difficulty coordinating video from UAS and TADS video. Fired missile out of constraints, shot wrong target. UAS video frozen for 5 minutes without CPG correction.

(Non-VUIT-2 Missions)

TSC SA:

- CMWS ineffective at altitudes aircraft at. Aircraft susceptible to SA missile threats. Pilot so low and inside that he allowed aircraft to come within 17 feet of ground contact.

- Friendly casualty in objective. Friendly given as in mangrove, north of 3a. Crew shot friendly.

- Poor MTADS tracking almost caused missile miss on ZSU.

Did the aircrew complete their mission objectives?

(Non-VUIT-2 Missions)

TSC MS1:

- Friendly was shot.

If no, why weren't the mission objectives completed?

(Non-VUIT-2 Missions)

TSC MS2:

- Fratricide.

Appendix C. Situation Awareness Ratings and Comments

This appendix appears in its original form, without editorial change.

SA RATINGS (VUIT-2 Missions)

Front Seat

'Demand' During Missions

| 13.38 |

Low   1------3------5------7------9------11------13------15------17------19------21   High

'Supply' During Missions

| 17.63 |

Low   1------4--------7--------10--------13--------16--------19--------21--------24------28   High

'Understanding' During Missions

| 14.75 |

Low   1------3------5------7------9------11------13------15------17------19------21   High
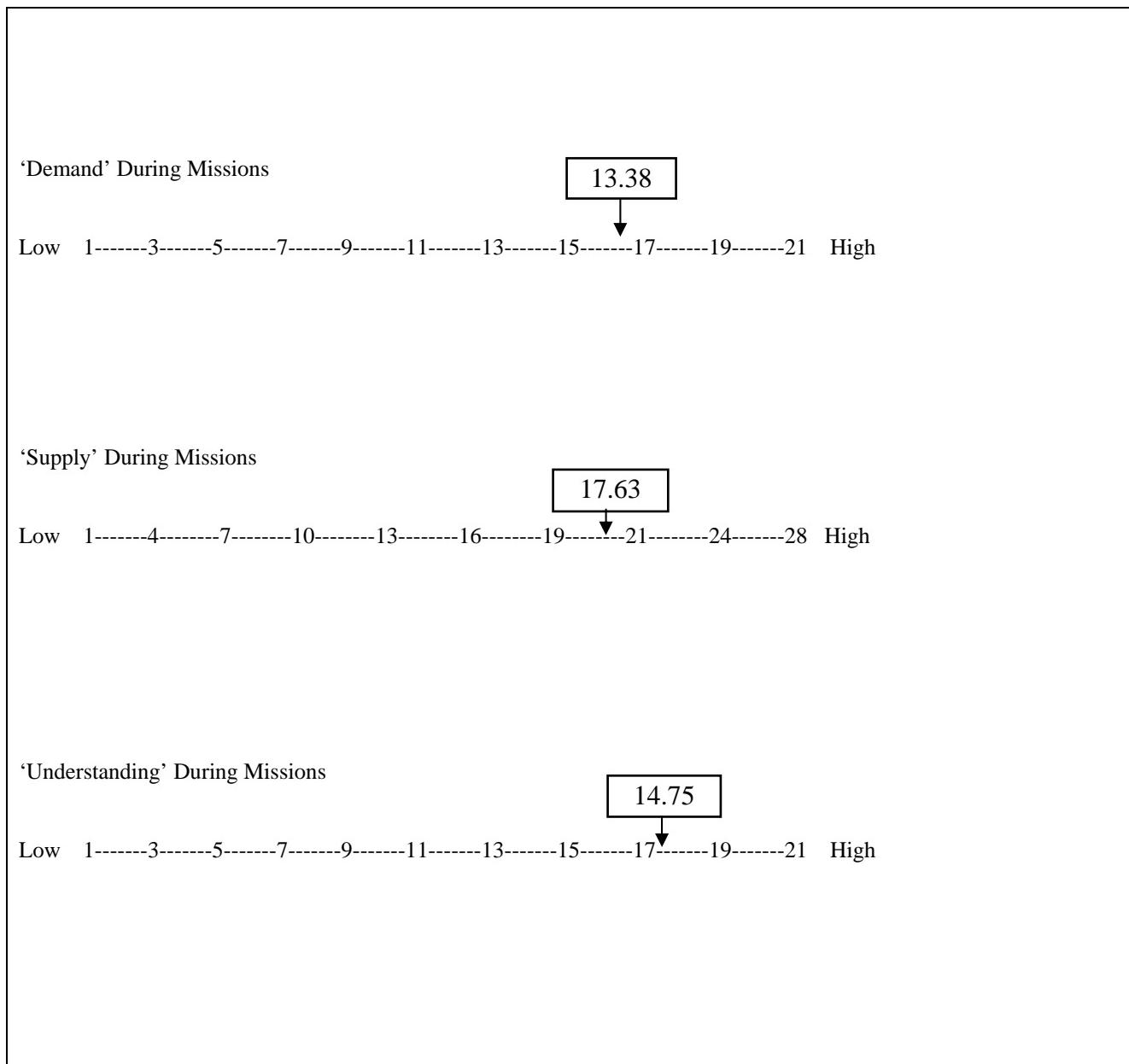
Overall SART Score: 19.0

Back Seat

'Demand' During Missions

| 12.5 |

Low   1-------3-------5-------7-------9------11-------13-----↓15-------17-------19-------21   High

'Supply' During Missions

| 18.88 |

Low   1-------4--------7--------10--------13--------16--------19-------↓1--------24-------28   High

'Understanding' During Missions

| 15.0 |
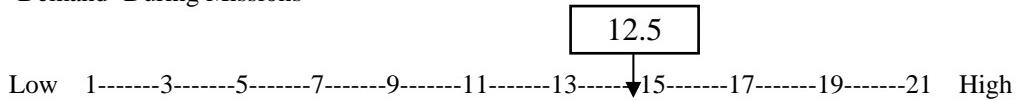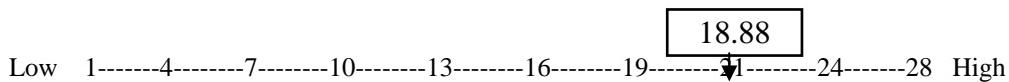
Low   1-------3-------5-------7-------9-------11-------13-------15-------17------↓-19-------21   High
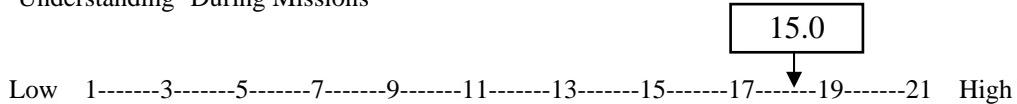
Overall SART Score: 21.38

SA RATINGS (Non – VUIT-2 Missions)

Front Seat

'Demand' During Missions

13.33

Low   1-------3-------5-------7-------9-------11-------13-------15-----▼-17-------19-------21   High

'Supply' During Missions

19.67

Low   1-------4--------7--------10--------13--------16--------19--------21-------▼24-------28 High

'Understanding' During Missions

13.33

Low   1-------3-------5-------7-------9-------11-------13-------15------▼-17-------19-------21   High

Overall SART Score: 19.67

SA RATINGS (Non – VUIT-2 Missions)

Back Seat

'Demand' During Missions

```
                                                            13.0

Low    1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21    High
```

'Supply' During Missions

```
                                                                    19.33

Low    1-------4--------7--------10--------13--------16--------19-------21-------24-------28    High
```

'Understanding' During Missions

```
                                                    11.67

Low    1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21    High
```

Overall SART Score: 18.0

Battlefield Elements Ratings (VUIT-2 Missions)

Battlefield Elements	Very High Level of Situation Awareness		Fairly High Level of Situation Awareness		Borderline		Fairly Low Level of Situation Awareness		Very Low Level of Situation Awareness	
	Front	**Back**	**Front**	**Back**	**Front**	**Back**	**Front**	**Back**	**Front**	**Back**
Location of Enemy Units	25%	38%	50%	25%	13%	25%	13%	13%	0%	0%
Location of My Aircraft During Missions	38%	38%	50%	50%	0%	13%	13%	0%	0%	0%
Location of Other Aircraft In My Flight	0%	0%	25%	25%	50%	63%	13%	13%	13%	0%
Route Information (ACPs, BPs, EAs, RPs, etc.)	25%	25%	38%	63%	25%	0%	13%	13%	0%	0%
Status of My Aircraft Systems (e.g., fuel consumption)	13%	38%	38%	38%	25%	13%	13%	0%	13%	13%

Battlefield Elements Ratings (Non – VUIT-2 Missions)

Battlefield Elements	Very High Level of Situation Awareness		Fairly High Level of Situation Awareness		Borderline		Fairly Low Level of Situation Awareness		Very Low Level of Situation Awareness	
	Front	**Back**	**Front**	**Back**	**Front**	**Back**	**Front**	**Back**	**Front**	**Back**
Location of Enemy Units	0%	0%	33%	33%	67%	67%	0%	0%	0%	0%
Location of My Aircraft During Missions	67%	0%	0%	100%	0%	0%	33%	0%	0%	0%
Location of Other Aircraft In My Flight	0%	0%	67%	33%	33%	67%	0%	0%	0%	0%
Route Information (ACPs, BPs, EAs, RPs, etc.)	0%	33%	33%	33%	67%	33%	0%	0%	0%	0%
Status of My Aircraft Systems (e.g., fuel consumption)	33%	0%	33%	67%	33%	33%	0%	0%	0%	0%

Pilot Situational Awareness Comments

APACHE UAS SA Comments

SA2 (VUIT-2 Missions):

- When the grid passed off by the battle captain was wrong, but the UAV feed cleared up the situation.

- Received no information on civilian areas but also didn't ask. I think as a P/C in the real world, I would take longer before allowing the CPG to shoot. I'd have him looking at collateral damage possibilities more. We had problems with getting correct grids for targets which is actually more realistic. The terrain was challenging (complicated more by the grid issues). Higher altitudes helped reduce workload immensely and kept me as the backseater from having the urge to get close because I wouldn't be able to see the target due to structure of the A/C.

- During the remote engagements, I had to put more attention to finding the UAVs location to me and the target.

- Location of friendly units. Need a BFT icon for UAV to provide location info to B/S. F/S has same degree of UAS location on VUIT map which was not available to pilot in B/S.

- Once Blackjack dismounted they entered the city. Commander didn't know where his soldiers were, so we quit shooting until he said they were clear. We got too close and would have taken damage, however based on the speed the lift and ground forces moved it's impossible to stay back. A lot of questions that an AMR with lift and inf would have corrected.

- When the troop got off of their A/C, I could not see them. I don't know if it was a LCT issue or if they went behind a building. I could not fire due to unknown location at first.

- I didn't keep up with the other A/C once we engaged. I still had no time to monitor A/C systems due to other activities.

- Location of my A/C – because of requirement to focus inside cockpit, location SA was lost a few times. Majority of the dwell time inside cockpit caused by similar limitation (no IHADSS boresight) some caused by CPG lack of familiarity with MTADS (only 3.0 hours).

- Difficulty remembering to unfreeze UAV feed.

SA2 (Non – VUIT-2 Missions):

- I was inside so much I could not keep a mental picture.

- We were uncertain of the location of the non combatants and the informant.

- Miscommunication in locating personnel.

Appendix D. VUIT-2-Crewstation Interface Ratings and Comments

P1. Did you experience any problems using the VIP keys during mission to accomplish UAV tasks? Place an X in the 'Yes' or 'No' column for each key listed below. If you checked 'Yes', explain the problems you experienced:

VIP Keys	Yes	No
1 – UAV MAP	67%	33%
2 – MTCDL PG	17%	83%
3 – BIT PG	0%	100%
4 – FRQ SCRL	67%	33%
5 – STR PIC	0%	100%
6 – RCL PIC	17%	83%
7 – ZM IN	17%	83%
8 – KEY INFO	0%	100%
9 – ZM OUT	0%	100%
0 – XMT O/O	17%	83%
CNCL *	33%	67%
NUM LOC #	33%	67%

UAV MAP

- Needed smaller icons. My icon needs same cues. Can't see UAVS holding cues.

- Map and icons are hard to read and see.

- Concerned that the system will no be able to hold enough map data.

- Detail is limited.

MTCDL PG

- Just needs faster means of fixing Freq.

FRQ SCRL

- Just need the ability back space or entry.

- Can't back out.

- Needs to have a data entry field of its own, instead of defaulting to data entry field on key 2 page.

- Labeled wrong, should be UAV pg.

XMT O/O

- This should be an enter also.

ZM IN

- It zoomed in on the same map, not different scales.

RCL PIC

- Need ability to delete saved images that are no longer required.

CNCL

- Need single space clear and backspace option available.

- Need to have a single back clear, not clear all as it is now.

NUM LOC

- Name and visual does not really correlate to the buttons function which is cursor select and data enter.

- Confusing why it is labeled NUM LOC.

P2. Overall, how quickly were you able to use the VIP keypad and switches to accomplish UAV tasks (e.g., data entry, toggling keys)?

1	2	2.7 → 3	4	5
Very Quickly	Somewhat Quickly	Borderline Slowly	Somewhat Slowly	Very Slowly
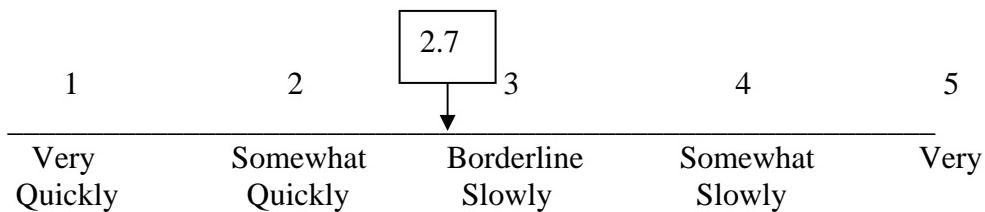
If 'Somewhat Slowly or 'Very Slowly', describe the problems you experienced:

- The buttons are too small for fast operation. There needs to be more streamline setup like a computer keyboard. "Just use the KU" keyboard unit in the A/C now.

- Rated "Somewhat Slowly" due to operator proficiency. I expect to improve with continued use. A second reason is the button functionality issues addressed on page 1 i.e. cncl clear function, key 4 data entry on key 2 page, etc.

P3. Was there any UAV symbology or wording depicted on the MPD that was difficult to quickly and easily understand?

- Yes 100%   No 0%

If yes, explain which symbology or wording was difficult to understand and why:

- Hard to see icon cues on map.

- The symbology was very hard to see on our MPD. The icons represented around 800 meters on the map scale, which we used. It made it hard to tell where everything was really at. You could not see the symbology which tells which way it was flying or looking.

- Lack of flight info (i.e. north arrow, UAS altitude, uas speed, uas direction of travel) for UAS. Lack of color symbols (i.e. sensor pointing direction) displayed on map.

- LOS arrow symbology should be black, not white and have a different symbol on the end. ----X

- The UAV line of sight arrow is difficult to break out from the background map.

- Symbology on the map page is too large for that scale of map. Need to have a North seeking arrow on VUIT video page.

P4. On average, how often did the design of the UAV interface (e.g., VIP, infor on MPD) significantly hinder you from quickly and easily performing UAV tasks?

(Circle one)

| 2.5 |
| 1 | 2 | 3 | 4 |
| Never | Seldom | Often | Frequently |
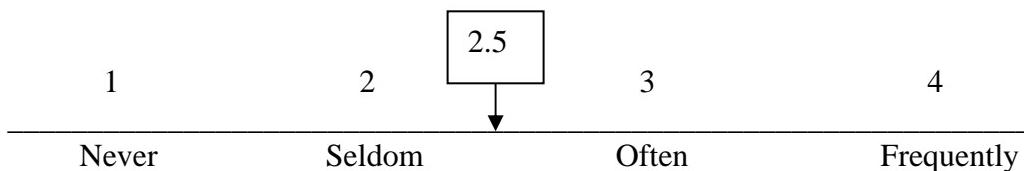
- If 'Often or Frequently', describe how the design of the UAV interface significantly hindered you from quickly and easily performing UAV tasks:

- Its just hard because its not integrated and your MPD usage is too much.

- Same as similar problems.

- Not having a back arrow or a dedicated "enter" button slows down our ability to quickly input the desired info.

P5. On average, how often did the design of the UAV interface contribute to high workload when controlling the UAV? (Circle one)

| 2.7 |
| 1 | 2 | 3 | 4 |
| Never | Seldom | Often | Frequently |
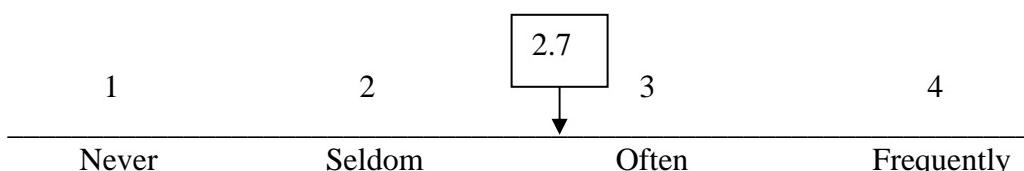
If 'Often or Frequently', describe how the design of the UAS interface contributed to high workload during missions:

- It was the whole problem.

- Same as similar problems

- Not having a back arrow or a dedicated "enter" button slows down our ability to quickly input the desired info.

P6. List any other UAV interface usability features that hindered your performance during the missions:

- Not being able to record your video at same time.

- Most important is inability to record VUIT video and coordinating communications with the on board A/C recording system.

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Appendix E. Top Improvements for VUIT-2 Integration

Top Improvements Recommended By Pilots

Video/VCR

- Need to be able to record on VCR as we receive VUIT video.

- Redesign to record UAV feed.

- Have two recorders so we don't have to switch ours off.

- Need to be able to record our TADS video without switching. People will forget to switch

- On board recording capability of VUIT video and comms.

Symbology

- Need to change the colors of the icon so we can scan them.

- LOS arrow needs to better break itself out from the background.

- Change MPD UAV symbol to black.

TSD Integration

- Needs to work with current TSD page.

- Have the UAV icon integrated on our TSD.

Map

- Need to see our site and heading on the map icon. Very important for remote. This will reduce the time.

- Map data fidelity.

- Need to have the ability of different scales of maps in the VUIT feed. Making the symbols scale to each map. Current symbols are too large for the 1:250k map.

Keyboard/Button Functionality

- Make sure the VIP works the same as the keyboard unit. Need an enter button, and backspace/clear button.

- Button functionality issues.

- Have a backup button when your inputting frequency.

- Need to have an "enter" button and a single space, backspace ability.

- Use a rocker switch for scroll and zoom, this will free up a couple of buttons for other functions.

Miscellaneous

- Being able to recall the MGRS grid after you have stored it.

- Get a standard format for the remote handover.

- Be able to select a preset frequency.

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Appendix F. Switch Actuations (UAS)

This appendix appears in its original form, without editorial change.

		Number of Switch Actuations Per Mission										
Column	Detailed Description	1	2	3	4	5	6	7	8	Avg	Std Dev	Max
TFOV	Left Hand Grip TAD FOV Select	66	54	24	20	153	130	126	80	81.625	50.04551	153
Slave	Right Hand Grip Slave Select	43	30	16	26	68	83	25	53	43	23.4094	83
Tracker	Left Hand Grip Tracker Switch	8	38	4	10	18	44	120	46	36	37.85687	120
Laser	Right Hand Grip Laser Trigger	24	21	6	3	41	51	60	64	33.75	23.68695	64
CPGR	CPG Right Bezel Buttons	43	44	3	38	20	29	21	35	29.125	13.93287	44
PLTL	Pilot Left Bezel Buttons	52	11	8	28	24	15	4	7	18.625	15.87395	52
PLTR	Pilot Right Bezel Buttons	45	6	22	10	25	0	21	7	17	14.38253	45
CPGL	CPG Left Bezel Buttons	32	16	39	5	21	0	6	8	15.875	13.8918	39
WpnTrig	Weapon Trigger	4	4	4	4	20	12	46	26	15	15.11858	46
WpnSel	Left Hand Grip Weapon Select	6	6	2	20	20	14	8	12	11	6.676184	20
TgtSt	Left Hand Grip Target Store	4	5	0	0	12	10	0	37	8.5	12.39816	37
LMC	Left Hand Grip LMC Select	3	8	0	4	1	6	0	10	4	3.741657	10
Sensor	Left Hand Grip Sensor Select	2	5	0	2	0	0	0	2	1.375	1.767767	5
DisB	TEDAC Display Brightness Rocker Switch	0	2	0	2	0	0	0	1	0.625	0.916125	2
TVidSel	TEDAC TADS Video Select	0	0	0	0	0	0	0	2	0.25	0.707107	2
Level	TEDAD Level Rocker Switch	0	0	0	0	0	0	0	1	0.125	0.353553	1
DisC	TEDAC Display Contrast Rocker Switch	0	0	0	0	0	1	0	0	0.125	0.353553	1
UFOV	UAV Field of View	0	0	0	0	0	0	0	0	0	0	0
Gain	TEDAC Gain Rocker Switch	0	0	0	0	0	0	0	0	0	0	0
PVidSel	TEDAC PNVS Video Select	0	0	0	0	0	0	0	0	0	0	0
SymB	TEDAC Symbology Brightness Rocker Switch	0	0	0	0	0	0	0	0	0	0	0
Scan	Left Hand Grip Scan Switch	0	0	0	0	0	0	0	0	0	0	0
UVidSel	TEDAC UAV Video Select	0	0	0	0	0	0	0	0	0	0	0
Map	Right Hand Grip Map Symbols Select	0	0	0	0	0	0	0	0	0	0	0
Sight	Right Hand Grip Sight Select	0	0	0	0	0	0	0	0	0	0	0
Enter	Right Hand Grip Enter for Cursor Control	0	0	0	0	0	0	0	0	0	0	0
Polarity	Right Hand Grip Polarity Select	0	0	0	0	0	0	0	0	0	0	0
	Sum	332	250	128	172	423	395	437	391	316	118.7121	437

Column	Detailed Description	Time of Movement								Avg	Std Dev	Max
		1	2	3	4	5	6	7	8			
TFCAz	RHG Thumb Force Controller Azimuth	396.7	374.2	202.3	100.2	880.5	494.9	685.2	915.7	506.2125	299.181	915.7
TFCEl	RHG Thumb Force Controller Elevation	369.6	360.1	217.5	113	877.1	475.3	646.5	860.9	490	282.8116	877.1
Cursor UD	Left Hand Grip Cursor Up/Down	0.01	0	0.01	0	0	104.9	0	0	13.115	37.08674	104.9
Cursor RL	Left Hand Grip Cursor Right/Left	0	0	0.01	0.01	0.01	0	0	0	0.00375	0.005175	0.01

VUIT - 2	1	2	3	4	5	6	7	8	Avg	Std Dev	Max
Button Presses	60	66	33	40	36	73	65	44	52.125	15.56037	73
Combined Total of Button Presses	392	316	161	212	459	468	502	435	368.125	126.0334	502

Switch Actuations (Non - UAS)

Column	Detailed Description	Number of Switch Actuations Per Mission				Avg	Std Dev	Max
		1	2	3	4			
TFOV	Left Hand Grip TAD FOV Select	224	140	126	196	171.5	46.25653	224
Tracker	Left Hand Grip Tracker Switch	68	86	26	123	75.75	40.30199	123
Laser	Right Hand Grip Laser Trigger	43	48	43	70	51	12.8841	70
Slave	Right Hand Grip Slave Select	81	47	36	26	47.5	23.92349	81
WpnTrig	Weapon Trigger	24	54	12	46	34	19.39072	54
Level	TEDAD Level Rocker Switch	46	30	4	1	20.25	21.54646	46
CPGR	CPG Right Bezel Buttons	12	28	18	15	18.25	6.946222	28
Gain	TEDAC Gain Rocker Switch	30	41	0	0	17.75	20.98214	41
WpnSel	Left Hand Grip Weapon Select	20	12	18	20	17.5	3.785939	20
CPGL	CPG Left Bezel Buttons	20	2	32	9	15.75	13.1244	32
TgtSt	Left Hand Grip Target Store	5	13	29	10	14.25	10.37224	29
PLTL	Pilot Left Bezel Buttons	34	11	6	0	12.75	14.86327	34
LMC	Left Hand Grip LMC Select	10	0	28	3	10.25	12.55322	28
PLTR	Pilot Right Bezel Buttons	7	3	12	7	7.25	3.685557	12
TVidSel	TEDAC TADS Video Select	3	13	0	0	4	6.164414	13
Sensor	Left Hand Grip Sensor Select	4	0	6	0	2.5	3	6
SymB	TEDAC Symbology Brightness Rocker Switch	0	8	0	0	2	4	8
PVidSel	TEDAC PNVS Video Select	0	5	0	0	1.25	2.5	5
DisB	TEDAC Display Brightness Rocker Switch	0	1	1	0	0.5	0.57735	1

DisC	TEDAC Display Contrast Rocker Switch	0	0	1	1	0.5	0.57735	1
Sight	Right Hand Grip Sight Select	2	0	0	0	0.5	1	2
Polarity	Right Hand Grip Polarity Select	0	1	0	0	0.25	0.5	1
UFOV	UAV Field of View	0	0	0	0	0	0	0
Scan	Left Hand Grip Scan Switch	0	0	0	0	0	0	0
UVidSel	TEDAC UAV Video Select	0	0	0	0	0	0	0
Map	Right Hand Grip Map Symbols Select	0	0	0	0	0	0	0
Enter	Right Hand Grip Enter for Cursor Control	0	0	0	0	0	0	0
	Sum	633	543	398	527	525.25	96.81727	633

		Time of Movement						
Column	Detailed Description	1	2	3	4	Avg	Std Dev	Max
TFCAz	RHG Thumb Force Controller Azimuth	983.4	820.4	1314.6	1061.8	1045.05	205.9175	1314.6
TFCEl	RHG Thumb Force Controller Elevation	961.8	796.6	1214.5	1034.8	1001.925	173.2409	1214.5
Cursor UD	Left Hand Grip Cursor Up/Down	18.5	0	0	0	4.625	9.25	18.5
Cursor RL	Left Hand Grip Cursor Right/Left	0.02	0	0	0.01	0.0075	0.009574	0.02

Time and Percentage of Time That Menu Pages Were Displayed on MPDs

UAS Missions

Title	CPG (Left MPD) Time (s)	%			Title	CPG (Right MPD) Time (s)	%
VCR Page	12930.5	73%			Wpt Page	8589.6	49%
Test Status Page	2900.9	16%			Test Status Page	3360	19%
Eng Page	673.7	4%			Route Menu Page	1605.3	9%
ABR Page	532	3%			VCR Page	1394.3	8%
Wpt Page	150.9	1%			Show Page	684.8	4%
Route Menu Page	150.7	1%			ABR Page	501.9	3%
Show Page	138.7	1%			Ctrlm Page	500.7	3%
Point Page	99.3	1%			DTU Page	392.2	2%
Load Page	49.3	<1%			Flt Page	231.7	1%
Video Page	43.7	<1%			Load Page	127.8	1%
DMS Page	26.3	<1%			Point Page	96.3	1%
Tre Page	7.6	<1%			Eng Page	82.1	<1%
Ctrlm Page	2.8	<1%			Video Page	81.8	<1%
					Freq Page	16.9	<1%
					Tre Page	11.7	<1%
					TSD Page	7.8	<1%
					Rpt Page	7.6	<1%
					Line Page	4.5	<1%
					AC Util Page	2.5	<1%
					Thrt Page	2.4	<1%
					Wpthz Page	0.7	<1%

Title	Pilot (Left MPD) Time (s)	%			Title	Pilot (Right MPD) Time (s)	%
Flt Page	4604.1	26%			Wpt Page	7497.2	42%
VCR Page	4413.8	25%			Video Page	5661.3	32%
Video Page	3117	18%			VCR Page	2699.1	15%
Eng Page	1988.8	11%			Test Status Page	771.2	4%
Wpt Page	1523.9	9%			Route Menu Page	539.2	3%
Test Status Page	669.6	4%			Eng Page	252.4	1%
Point Page	555.2	3%			Point Page	54.8	<1%
ABR Page	254.3	1%			Show Page	46.7	<1%
Perf Page	235.5	1%			Flt Page	40.8	<1%
Wpn Util Page	210.9	1%			AC Util Page	33.7	<1%
Show Page	39.7	<1%			ABR Page	31.6	<1%
TSD Page	26.9	<1%			Ctrlm Page	22.8	<1%
Fuel Page	24.5	<1%			TSD Page	12.8	<1%
Load Page	12.4	<1%			Perf Page	12.7	<1%
Freq Page	11.2	<1%			Tre Page	12	<1%
Tre Page	7.5	<1%			Rpt Page	9.1	<1%

Title	Time (s)	%		Title	Time (s)	%
ASE Page	7.2	<1%		Fuel Page	8.9	<1%
AC Util Page	3.7	<1%				
DMS Page	0.9	<1%				

Non-VUIT-2 Missions

	CPG (Left MPD)				CPG (Right MPD)	
Title	**Time (s)**	**%**		**Title**	**Time (s)**	**%**
Test Status Page	5993.3	72%		Wpt Page	7573.4	87%
Eng Page	835.4	10%		Route Menu Page	335.8	4%
Flt Page	709	9%		DTU Page	327.5	4%
ABR Page	458.9	6%		Test Status Page	160.3	2%
ASE Page	105.9	1%		Ctrlm Page	100.5	1%
Load Page	85	1%		Load Page	68.8	1%
TSD Page	17	<1%		Point Page	30.4	<1%
Wpt Page	13	<1%		ABR Page	21.3	<1%
Point Page	10.5	<1%		TSD Page	16.1	<1%
Video Page	10.3	<1%		Show Page	11	<1%
AC Util Page	10.3	<1%		Freq Page	8.9	<1%
VCR Page	6	<1%		VCR Page	6	<1%
Show Page	4.3	<1%		Tre Page	5	<1%
Tre Page	4.2	<1%		Video Page	0.8	<1%
Fuel Page	3.6	<1%		TCDL Util Page	0.7	<1%
WCA Page	3.1	<1%				
Sys Page	1.8	<1%				

	Pilot (Left MPD)				Pilot (Right MPD)	
Title	**Time (s)**	**%**		**Title**	**Time (s)**	**%**
Flt Page	3190.5	37%		Video Page	4010.4	46%
Wpt Page	2899.9	33%		Wpt Page	3584.6	41%
Eng Page	2003.4	23%		Flt Page	514.5	6%
ABR Page	172.7	2%		VCR Page	363.6	4%
Test Status Page	126.8	1%		Show Page	142.1	2%
Test Rgp Page	74.2	1%		ABR Page	23.6	<1%
Ctrlm Page	59.9	1%		Tre Page	7.3	<1%
Wpn Util Page	42.7	<1%		Point Page	1.9	<1%
VCR Page	29	<1%				
TSD Page	18.5	<1%				
Video Page	15.1	<1%				
Point Page	12.7	<1%				
Show Page	9.3	<1%				
Fuel Page	6.3	<1%				
Tre Page	4	<1%				
Wpn Page	1.5	<1%				

Appendix G. Operations Order

1. Situation:

a) Enemy Forces

  1) Situation

    a. Enemy – Enemy forces are operating all across the battle space. Enemy forces are loosely organized into small teams which act independently in support of a larger objective of destabilizing the local government and swaying the local populace against allied forces.

    b. Weather – clear, winds are 180/5 G10, vis >7 mile.

  2) Capabilities - These teams are normally made up of local 20 – 40 year old men with the likely-hood of a non-local formally trained team leader. Their weapons consist of small to medium caliber weapons, mortars, rockets, SA7s or 16s, mines and IEDs. They normally will go to ground in the event of attack but are not reluctant to stand and fight if their home or leader is threatened. Sympathetic boarder nations have been supplying the enemy forces with weapons that are becoming increasingly lethal. The border nations have also pre-positioned small armored units near the boarder as a show of force and to deter allied nations from cross-border pursuit. The units have been known to surge forward toward the border to provoke a response from allied forces but have stopped short of crossing the international boundary.

  3) Probable course of action - Their most probable course of action is to ambush allied forces using mines, IEDs and SAMs followed by small arms fire with a quick retreat before allied re-enforcements arrive. Their most dangerous course of action is to ambush allied forces using mines, IEDs and SAMs followed by a deliberate defense of the target area to delay allied forces. This may be supported by a cross border incursion of the border nation to aid in the destruction of the allied forces or withdraw of the local enemy insurgent back to the sanctuary of the border nation.

    b) Friendly Forces.

  1) Mission of Next higher unit. – 1-14th Aviation Regiment mission is to support 3BCT with attack helicopter support to prevent or deter enemy forces from disrupting 3 BCTs movement.

  2) Mission of adjacent units – 1st and 2d BCT are conducting similar missions in the city and plains sector of the battle space.

  3) Mission and location of supporting elements

    a. HHC 1-14th (Heavy) is located at the 1-14th Assembly Area with the mission to provide class 3/5.

b. 2-14th (Warlock) is located at the 1-14th Assembly Area with the mission to provide lift capability to 3BCT.

c. JSTARS is on station as directed to provide over-watch and Intel on NAIs as directed.

d. A Co UAV (Shadow) is located at 1-14th Assembly Area with the mission to provide over-watch and Intel for the 3BCT and supporting elements as directed by 3 BCT.

e. 1-15th In (Blackjack) is located at the 1-14th Assembly Area with the mission to prevent insurgent activity in their area of operation and to destroy insurgent forces operating in their battle space.

2. Mission:

B Company 1-14th Aviation Regiment will conduct route and area recon in support of 2-14th Air Assault into objective Red to prevent hostile engagement of friendly forces. On order, conduct Close Combat Attack to destroy enemy forces in objective red to prevent the delay of 1-15th Infantry's advance into the objective. Be prepared to conduct a hasty attack to destroy units moving from the border nation in order to prevent their influence on the objective.

3. Execution:

a) Concept of Operation. Will be an Air Assault 500m North of objective red by 1-15th Infantry with recon and over-watch provided by B Company 1-14[th.] Once on the ground 1-15th will advance into objective red to destroy enemy forces.

1) Scheme of maneuver. B 1-14th will depart with 2-14 Avn Assets to conduct route and area recon. Once at the objective, B 1-14 will set-up in an over-watching position of the objective to provide fires for 1-15th infantry. B 1-14th will then conduct relief on stations to provide continuous over watch of the objective until released by 1-15th or higher headquarters.

2) Formation. Teams abreast

3) Route. Ingress – Route Falcon

   Egress – Route Sparrow

4) Tactical Missions to subordinate Units.

   a) A Company UAV - will depart prior to B 1-14th departure to have the UAVs on station at vicinity of Waypoint 2 and LZ. A UAV will provide route and area recon while another recons the LZ and Objective Red.

   b) 3-17th FDC – will provide priority fires to 1-15th and B 1-14th Aviation for the entirety of the mission.

5) Coordinating Instructions. B Company 1-14th and A Company UAS will conduct a commo check prior to departure and a UAS video link-up when within range of the UAV in the vicinity of Waypoint 2 (CC). Additional control will be governed by the direction of the 1-15th ground commander.

4. Service Support:

a) Ammunition load is 300 rounds of 30mm, 12 rockets and 8 Hellfires.

b) Fuel is 2+30.

5. Command and Signal. See Communications Card

List of Symbols, Abbreviations, and Acronyms

AAR   after-action review

AB3   Apache Block III

ACP   Air Control Point

AH   Attack Helicopter

AOI   area of interest

ARH   Armed Recon Helicopter

ARL   U.S. Army Research Lab

ASL   Applied Science Laboratories

ATM   Aircrew Training Manual

BWRS   Bedford Workload Rating Scale

CDD   Capability Development Document

CONOPS   Concept of Operations

CPC   Comanche Portable Cockpit

CPG   copilot-gunner

DIS   distributed information system

EDS   Engineering Development Simulation

EUD   Early User Demonstration

FAC   Flight Activity Category

FCR   fire control radar

FOV   field of view

HRED   Human Research and Engineering Directorate

ICS   interphone communication system

LEUE   Limited Early User Evaluation

MPD   multi-purpose display

MTADS	modernized target acquisition and designation sight
MTCDL	mini-tactical common data link
NOE	nap of the Earth
NVG	Night Vision Goggles
OneSAF	One Semi-Automated Forces
OSRVT	one system-remote video terminal
PI	pilot (pilot in back seat who flew the aircraft)
PMO	Product Manager's Office
PNVS	pilot night vision sensor
RACRS	Risk and Cost Reduction Simulator
RL	Readiness Level
SA	situation awareness
SART	Situational Awareness Rating Technique
SME	subject matter expert
SSQ	Simulator Sickness Questionnaire
TCDL	Tactical Common Data Link
TEDAC	TADS Electronic Display and Control
TRADOC	Training and Doctrine Command
TS	Total Severity
TSD	Tactical Situation Display
TSM RA	TRADOC System Manager, Reconnaissance Attack
TTP	tactics, techniques, and procedures
UAS	unmanned aerial system
UCI	UAS Crewstation Interface
UHF	ultra high frequency
VFR	Visual Flight Rules
VIP	VUIT Interface Panel

VMC   Visual Meteorological Conditions

VUIT-2   Video from UAS for Interoperability Teaming Level II

WSRT   Wilcoxon Signed Ranks Test

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